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SOUND-RANGING.*

BY

AUGUSTUS TROWBRIDGE, Ph.D., D.S.M., D.S.O., Chev. L.H.

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In the autumn of 1914 the French first undertook experiments to determine whether the enemy artillery positions could be located by means of the sound of the firing of the guns. These experiments met with sufficient success to warrant the establishment of sound-ranging sections along the entire western front. When the British arrived in force in France they also established a sound-ranging service which employed apparatus which was somewhat more elaborate than that adopted by the French and which was especially designed to meet conditions on a very active front.

When, in the early opening of 1917, the first American troops went into the line American sound-ranging sections went in with them, equipped with apparatus furnished by the British and directed by officers who had been trained in their special duties on the British front. At the same time other American sound-ranging troops were being trained in the back area and apparatus was being constructed in America with which to provide the sections which were needed when the steady flow of American combat troops began to arrive in France.

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, October 23, 1919.

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At the signing of the armistice a battalion of ranging troops consisting of five companies was in France; about one-half of the battalion was engaged in sound-ranging and the other half in the special form of visual observation known as flash-ranging.

PRINCIPLES OF SOUND-RANGING.

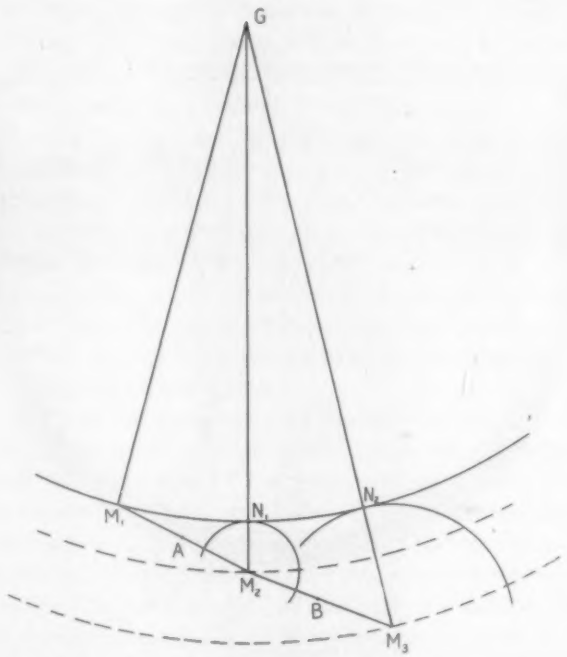
Sound travels in still air at zero degrees centigrade (the freezing point of water), at the rate of 330.6 metres per second (roughly 1100 feet per second). At 10 degrees centigrade the speed to the nearest whole number is 337 metres per second. The velocity is not only affected by the temperature of the air, but also the *apparent* velocity is very markedly affected by the velocity and direction of the wind. It follows from this that a survey carried out by the means of sound waves unlike a survey carried out in the ordinary manner by light waves is subject to errors introduced by the lack of accurate knowledge of the wind and temperature corrections which it is necessary to apply to the data of observation. Furthermore there is a lack of parallelism between a light survey and a sound survey which will be evident from the following consideration: To locate a point on the ground by a light survey it is only necessary to secure an intersection of two light streams towards two known points on a surveyed base line by the use of relatively small telescopes, while to obtain a location at all comparable in accuracy by means of sound it would be necessary to use instruments of prohibitively great size. Fortunately, however, advantage may be taken of the low velocity of sound compared to that of light to obtain a survey from *three* points without the use of listening apparatus of great size. This method entails the accurate measurement of the *differences* of times of arrival of sound at the three points. This, of course, entails the use of some form of accurate clock, and precludes the use of human observers who might differ too much in their reaction times.

In still air at 10 degrees centigrade the sound from a gun moves out in a wave of compression and rarefaction which travels 337 metres per second. If the gun is at G and mechanical listeners electrically connected to a common timing device are situated at M_1, M_2 and M_3 and if, for example, GM_1 be 3370 metres, the sound of the gun will reach M_1 in 10 seconds, and the front of the spherican wave will go through M_1, N_2 and N_3. This wave front moving with the velocity of 337 metres per second will reach M_2

later than it reaches M_1. How much later is determined by the time it takes the sound to travel the distance N_1, M_2.

Thus the interval between the arrival of the sound at M_1 and at M_2 will be $\frac{N_1 M_2}{337}$ seconds, and the interval between the arrival at M_1 and at M_3 will be $\frac{N_2 M_3}{337}$ seconds. Suppose the distance $N_1 M_2$ were 33.7 metres, then the interval of time between the arrival at

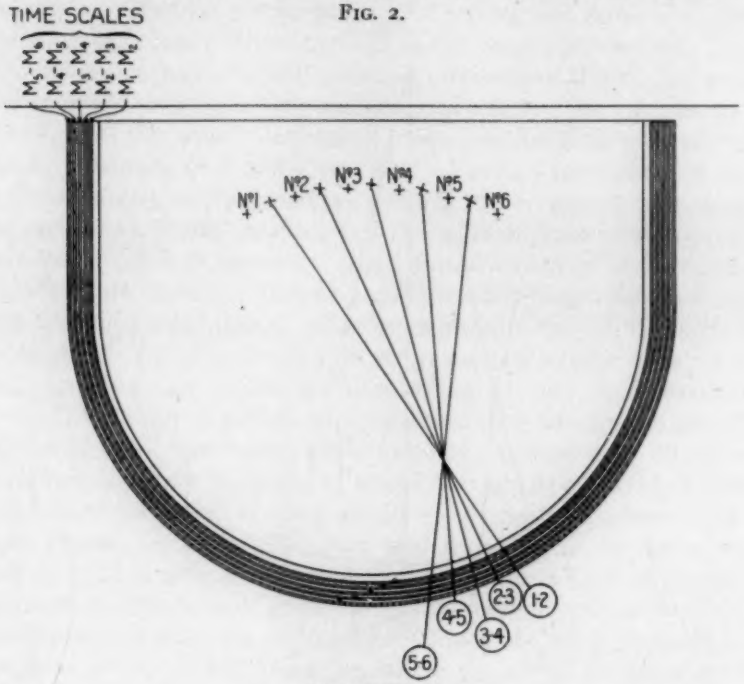
FIG. 1.



M_1 and at M_2 would be one-tenth of a second, and this time would be recorded on the timing device electrically connected with M_1 and M_2. This interval alone would not serve to locate the position of the gun, for there are a whole series of positions which the gun might occupy and still send the sound to M_1 a tenth of a second earlier than to M_2—in fact G might lie anywhere provided GM_1 were greater than GM_2 by 33.7 metres in the example chosen. Stated more mathematically, G must lie on a particular hyperbola having M_1 and M_2, as foci for an hyperbola is a curve drawn so

that the difference of the distances from any point of the curve to the two fixed points, or foci, is a constant (33.7 metres in this case). Now if G is not close to M_1 and M_2 compared to the distance between M_1 and M_2, which is the practical case on the battle front, the hyperbola on which G must lie is practically a portion of a straight line which, if prolonged, goes through a point midway between M_1 and M_2 and thus it is possible to determine the *direc-*

FIG. 2.



Plotting board.

tion from this mid-point. A plotting board may be prepared in advance which has a string pivoted on the mid-point A, and a scale on the edge of the board marked with hundredth and tenth second intervals. In the example chosen this string would have to be set at the point marked "1/10th second left" and the gun would be determined to lie on the ground at some point represented on the plotting board as a point lying under the string. Similarly if the observed interval between the times of arrival of the report at M_2 and M_3 be laid off on a second scale for string

pivoted on the mid-point B the intersection of the two strings would locate on the plotting board the position of the gun on the ground. Naturally the plotting board must be very carefully prepared from an accurate survey of the positions of the listening instruments on the ground.

The location found on the plotting board will only be exact without correction if the temperature of the air is 10 degrees centigrade and if there is no wind. If there is no wind but the temperature is greater than 10 degrees centigrade the sound will have travelled more rapidly than was assumed in the preparation of the plotting board and the intervals will thus be too small for the scale adopted in drawing the board. The amounts by which the intervals must be augmented if the temperature of the air be known are easily calculated and the strings may be set for the corrected intervals, and the intersection determines the true position of the gun as before. If a wind be blowing with a known velocity in a given direction it is only the components of this velocity which lies along the directions GM_1, GM_2, and GM_3 which will affect the times of arrival or the sound at the listening instruments; the observed intervals may therefore be easily corrected to what they would have been were there no wind and the plotting strings set accordingly.

The theory of the application of the wind and temperature corrections is an extremely simple matter, and the application itself is easy and rapid because of the graphical method of calculation employed in the construction of the string plotting board. The real difficulty lies in an uncertainty as to what the true temperature and wind are since the sound comes by a path inaccessible to observation. More than half of the path lies behind the enemy lines and the remainder lies in a region in which it is not permissible to attract the attention of the enemy by carrying out any unnecessary activities.

Three listening instruments electrically connected with a "central" or calculating station are theoretically sufficient to permit of a survey of the enemy batteries by sound; however, it is in practice advisable to employ more than three instruments for the following reasons: The electrical connections between the instruments and the time-recording mechanism at the "central" are unavoidably subject to considerable cutting by the enemy's shell-fire; it is out of the question to bury the lines to a sufficient depth

to avoid all cutting and a shallow bury renders the location and repair of breaks which do occur extremely difficult; the practice has been to lay the lines exposed on the ground and to provide a sufficient force of linesmen to ensure quick repairs. In order that the section may continue its work while such repairs are being made, six listeners instead of three are provided in the expectation that at least three will always be in working condition. If only the minimum number (three) of listening instruments are employed, no estimate of the accuracy of a location can be formed, whereas if six instruments be used the location is determined by the intersection of five strings on the plotting board; if these all intersect in a point the location is probably accurate, whereas if the intersection is poor the location is probably badly in error. A study was made of the errors corresponding to certain typical intersections and a general plan of reporting the probable accuracy of the location from the character of the intersection was adopted. The officer in command of a sound-ranging section thus reported to the artillery not only the location, target and probable calibre of an active enemy battery but also whether the location was probably accurate to fifty, one hundred or one hundred and fifty metres; these estimates were formed in a scientific manner, and all of the various sections on the front employed the same method. After a considerable number of the enemy's battery positions had been captured it was possible to check up the errors of the individual sound-ranging locations with the results of a careful survey of the positions; it was found that the estimates of accuracy had been rather too conservative, for in none of the cases examined was the accuracy less than had been claimed when the report was made, and in the majority of the cases it was considerably greater.

The recording mechanism at the "central" consisted of an accurate timing device arranged so as to photograph on a moving strip of sensitized paper a series of lines about one-fiftieth of an inch apart; these lines were the shadows cast by a set of spokes of a wheel which was kept spinning in the path of a beam of light which fell on the sensitized paper; the rate of spin of the spoked wheel was governed by a tuning fork so that the shadows were cast on the paper with the greatest attainable regularity; the rate chosen was one hundred shadows per second, so that the photographic paper had recorded across its entire width an extremely accurate time scale, the smallest interval of which was one one-

hundredth of a second; the tenth second mark and the entire second mark were made so as to be easily distinguishable from the others in order to permit rapid counting The photographic paper employed was of the standard moving picture film width, as this could be obtained quickly and at low cost both in Europe and America.

Superimposed on the time scale on the photographic paper were six lines equi-spaced across the width of the paper; these were the shadows of six moving elements of a specially constructed galvanometer, each of whose six moving elements were electrically connected to a certain one of the six listening instruments on the sound-ranging base. When the sound of an enemy gun arrived at listener No. 1 there occurred a slight twitch in the element No. 1 of the galvanometer, and this twitch was photographed on the moving photographic paper strip. The time the twitch occurred could be estimated with an accuracy of at least a hundredth of a second because the record of the time was superposed on the same piece of photographic paper. When the sound arrived at listener No. 2 the element No. 2 of the galvanometer recorded in a similar manner the exact time of arrival, and the same was true when it arrived at the listeners connected with the other four elements. Thus if the mechanism were set in motion before the sound of the gun reached the listener nearest to the gun and was allowed to run until the sound reached the listener farthest from the gun, the photographic record which was automatically developed and fixed contained all the information necessary to calculate the gun position; *i.e.*, it contained the five *intervals* between the times of arrival at the six listening instruments; if, as was generally the case, the recorder was run for twenty or thirty seconds the record usually contained the record of the burst of the enemy's shell and the position of this could also be reported to the artillery within from one to two minutes after the gun had fired.

Since a typical record not only contained data from which the position of the enemy gun could be located, but also contained data from which the location of the burst of the shell could be calculated, both the range and time of flight of the shell could be calculated. In the case of guns employing fixed ammunition charge, a knowledge of these two quantities was sufficient to determine the calibre of the gun, since the values of the muzzle

velocities of many of the German guns were well known to the Allies. Even in the case of guns not employing fixed ammunition charge the fact that the burst of the shell could be located enabled the officer in charge of the section to recover fragments of the shell on which to base an estimate of the calibre.

The possibility of an estimate of the calibre of the enemy guns was one of the unique features of sound-ranging—another important feature was the ability to locate guns which were brought up by the enemy in preparation for an attack and which were therefore not used in the period preceding the attack in order to insure an element of surprise. Such guns usually fired but one or two ranging shots, and if they were well concealed usually escaped detection by ordinary means; many such guns were located by sound-ranging when they fired their ranging shot or shots.

ACCURACY OF SOUND-RANGING IN THE A. E. F.

The limitation to the accuracy attained by the sound-ranging in the A. E. F. was partly scientific and partly set by practical working conditions. As regards the latter it is of course obvious that the necessity of mobility, the fact that any system must be operated by rather hastily trained men of average intelligence, the fact that results must generally be reported quickly to be of the greatest service, and finally the fact that an accuracy greatly in excess of that of modern artillery fire is not necessary, all preclude the use of apparatus designed solely with the object of attaining great accuracy.

The scientific limitations are in part geometrical, in part meteorological and only in part instrumental. Sound-ranging is of course a type of survey, and the accuracy to be expected is in part determined by the length of the base.

We have used six listeners equi-spaced along the arc of the circle concave toward the enemy and with the centre of the circle at or near the point about which the enemy's artillery has been grouped in the sector. This generally results in the radius of the circular arc being from 20–30 sound-seconds in length and the distance between listeners on the arc being 4, 4½ or 5 sound-seconds. (One sound-second is 337 metres.) The combination 25 sound-second radius and 4½ sound-seconds interval has been most used. Straight bases (R=infinity) have been used. The practical objection to the straight base that their use in general

results in longer films to a record is not very serious, while the theoretical objection that every location is capable of two solutions, one in front and one behind the line of listeners, applies only to the location of shell-bursts, which is a matter of no practical importance. Bases of more than 5 sound-seconds interval, while they would result in increasing accuracy, would be difficult to keep in operation on an active front because of wire cutting. On a quiet front a base of 6 seconds might be used to good effect, but it would probably have to be shortened if the front became active and this would leave a gap between neighboring sections. A better plan to secure the advantages of a long base is one we had in operation in preparation for the siege of Metz; this was to lay out adjacent sections so that they could be coupled to form one section of very long base for the more accurate location of guns of the heavier calibres.

The meteorological limitations were the most serious; these were quantitative and qualitative; that is, the exact knowledge of the direction and magnitude of the wind and the temperature were generally lacking, so that wind and temperature corrections were uncertain. Much was done to reduce this uncertainty by the British, who employed so-called wind sections near the front where empirical corrections were determined by the use of sound-ranging apparatus to secure the sound coördinates of a source of sound whose geographic coördinates were known. The factors necessary to convert the sound coördinates to the geographic were telephoned every two hours to the sound-ranging sections. This empirical method of applying wind and temperature corrections served its purpose very well and as a by-product furnished some material which should be interesting to the meteorologist. We never had to use wind sections in the A. E. F. because it was found by comparison of the data of the wind sections and those of the Army meteorological service that the actual wind velocities, directions, and temperatures, existing at a height of 50 metres gave the same over-all corrections as those obtained from the wind sections.

The limitations referred to as qualitative above were more serious. When a strong wind was blowing towards the enemy the sound was bent up so that it did not reach the listening instruments. When the wind blew from the enemy the sound reached the listeners well but the character of the records was rendered

less sharp, and so inaccuracies in the time intervals were introduced. Irregularities in temperature also produced analogous "mirage" effects which confused the records. Generally winds tended to reduce accuracy, for they necessitated screening of the listeners, which resulted in a slight decrease in sensitivity. Good screening was possible, however, and latterly the use of transformers in the circuit was coming into use. This was used first by the Americans and was given a try-out by the British, and would probably have been adopted by both services as it did away entirely with a number of electrical complications and completely removed the irregular slow-period fluctuations due to poor wind screening. Lastly, there were instrumental limitations. Lack of sensitivity was *not* one of these—it is true that with a more sensitive recording instrument the listening instruments might have been further in the rear and greater safety to the men and less wire cutting would have resulted; however, the importance of the wind and temperature corrections which are the uncertain elements in sound-ranging would have been increased, and more than this, it was our experience that the nearer the front a section was the more efficient it was. The men kept in better touch with what was going on and had a lively interest in locating and silencing the enemy batteries whose shells fell close to the section. Besides we were able to obtain the highest grade of enlisted man for the service because it was in a sense a front-line proposition. This would not have been so had we installed our sections further to the rear. The chief danger of instrumental inaccuracy was in the timing device. The French used clockwork, which was unreliable. We, copying the British, used a timing device governed by a tuning fork which we found satisfactory with modifications suggested by a special study made to determine the effect on the rate of the fork of contact pressure, level, amplitude, mass of fork, etc. The rate of the forks was checked from time to time as an error in the timing is of course fatal to accuracy. However, instrumental timing errors are not as fatal as irregular errors in the time intervals due to meteorological causes since the instrumental errors are at least systematic and affect all the intervals proportionally while the irregular errors may amount to a large portion of the interval.

A theoretical examination of the effect of unsystematic errors leads to the result that they are about seven times as great in

range as they are in line, and that they are less the longer the sound-ranging base. Likely errors from this source in average weather and for the type of base most used are from 30–40 metres in range. In good sound-ranging weather these errors are absent. Errors likely to be introduced from lack of exact knowledge of the wind in average weather are about 30 metres, while those from uncertainty as to temperature are pratically negligible. Neither of the latter is dependent on the length of the base.

An estimate of the probable over-all error of one observation including that due to geometrical causes is expressible as follows: In the normal battle area for a 4½ second base of 25 sec. radius the probable error of a location on the right bisector to the base would be 20 metres at 4 kilometres and 80 metres at 12 km. Along a parallel to the right bisector drawn from a flank of the base it would be 50 metres at 4 km. and 100 metres at 12 km. Most of the heavy calibre guns are grouped 7 or 8 km. from the base, and the bulk of the field guns lie from 4 to 7 km. from the base.

After September 10, 1918, it was possible to survey the captured German battery positions in the St. Mihiel salient and compare the locations made by the sound-ranging with the actual surveyed positions on the ground. The locality was very favorable for a study of the accuracy of sound-ranging for two good sections had been working in the region for a period of six months —in fact from the date of the entry of the first American division into the line.

The survey was performed by the Army topographic troops, who had no direct interest in the results. The sound-ranging locations of the various active batteries were obtained from the card catalogues of activity and locations kept throughout the six months: each location bore an estimate of the probable accuracy based on the character of the intersections on the graphical plotting board at the time the location was made. The same system was in use throughout all the sections and was as follows: *P*—error not more than 50 metres, *Q*—not more than 100 metres, *R*—not more than 150 metres, *RR*—more than 150 metres. In most cases there were a considerable number of locations of each battery so that weighted mean values of the coördinates could be taken. The system of weighting was to count *P* four, *Q* three, *R* two and *RR* one.

Captain C. B. Bazzoni, Engineers, prepared a very interesting

report on the accuracy obtained by Sections 1 and 3 of which he was in command for the period March to September, 1918, an extract from which is given below. This report we had printed and distributed to all superior officers, Staff and Artillery, in the A. E. F., and to the Belgian, British, French and Italian officers in charge of sound-ranging in the armies of these nations.

The P, Q and R ratings as referring to any one location give the computing officer's critical estimate of the technical excellence of the determination. These locations result from a mathematical-physical procedure of such a nature that, if the wind and other corrections are properly applied and the atmospheric conditions are properly evaluated, the final result must positively indicate the exact source of the sound. There are in practice always certain possible errors, the limits of which must in each case be estimated by the computing officer. Although the computing officer's estimate will be more or less valuable, depending on his general grasp of the physical problem and on his knowledge of the determining factors and of their mode of variation, the data here submitted show that in our service these estimates were generally fairly true. It is evident that P locations average better than Q, Q's better than R, and R's better than RR's, and that a location, judged by a competent computing officer in the light of known weather, instrument and line conditions to be within the limits of error of one of these categories, is to a high probability actually within these limits. There are, nevertheless, possibilities for a considerably greater variation in any one individual location than might be expected. These variations are due largely to an insufficiently accurate knowledge of the weather conditions.

It is clear that since the nature of the errors involved is accidental, the average of any considerable number of locations, in themselves inaccurate, is certain to be of a much higher degree of dependability. Four or five locations made under different weather conditions constitute a considerable number in the sense here used, and the mean of these four or five can be depended upon to be close to the true battery location, even though the constituent data are all of "R" accuracy. These facts are fairly well demonstrated by the evidence examined. This statement can be otherwise expressed by saying that five or more independent "R" locations enable us to place a battery with "P" accuracy or better. It is because of these facts that Section Commanders in our service have been directed to distinguish in orders of accuracy the accuracy to be ascribed, in the judgment of the computing officer, to any one location and the accuracy of determination of a battery position from a series of observations. The order of accuracy of the mean position will, as above pointed out, be always higher than that of the constituent data and can only properly be determined through a consideration of the number of independent values involved in the mean. A battery location should be rated R on a single determination because of our necessarily uncertain knowledge of the weather conditions, although the film itself may be judged

P or Q. A "Q" can, however, safely be given to the weighted mean of four or five locations irrespective of the ratings of the individual determinations and a P can similarly be assigned to the weighted mean of eight or ten locations. The attached data show that a P battery location is safe to 25 metres. The principal factor entering into the accuracy rating of a battery position is seen to be the number of locations obtained of whatever accuracy, but it will be understood that the giving of an order of accuracy to a battery location cannot be reduced to a mere mechanical consideration of the number of independent determinations involved, even though it is mainly based on this number. The grouping of the locations should be considered and should be found normal. A normal grouping is roughly elliptical with an axial ratio of 1 to 3 or thereabouts. The major axis lies roughly on the line, battery to centre of base chord.

The batteries discussed in the group covered by this paper (The Mont Sec group) are selected from this group as typical. Persons studying this report can safely accept the conclusions to which it leads without waiting for the reports on other groups. There is no essential difference in the character of the results obtained in the different groups or in the batteries of any one group.

We can sum up by saying that a single Sound-Ranging location rated P, Q or R is to a high degree of probability within the limits of error stated for these ratings; that a mean Sound-Ranging location comprising seven to ten or more individual determinations is to a considerable degree of certainty within 25 metres of the activity centre of the battery. In consequence it is probably just to conclude that Sound-Ranging is in general practice more dependable for compiling lists of active batteries and for detecting the active part of a given battery, than any other agency. It should, however, be pointed out that the highly technical procedures involved and the breadth of general scientific knowledge required to get results of this grade consistently, demand a highly qualified, highly trained and experienced personnel and a properly handled apparatus of the general character of that in use by our sections.

The attention of readers of this report is directed to the fact that the methods used for locating active batteries by Sound-Ranging are not the ones made use of in ranging our artillery on an objective. The placing of the bursts relative to one another is accomplished by other procedures, which enable us to report the relative positions to a considerably higher degree of accuracy. It will be seen that a dispersion of locations of successive bursts, such as is shown on the attached map squares, would be of no use in correcting artillery fire. This dispersion results from the dissimilarity of weather conditions on different days. The results obtained from any one battery at any one time, roughly speaking, within three or four hours, invariably check very closely indeed with one another; but these successive determinations do not appear on our records, being looked upon as duplications.

An idea may be gained of the *amount* of artillery information supplied by the sound-ranging sections from the following extract

taken from the report of the artillery information officer of one of the American corps. This officer had at the time as sources of information three American sound-ranging sections, two American and three French flash-ranging sections, aviation and observation balloons. During a period of three weeks of rapid advance 425 separate locations of enemy batteries were made; of these the two American flash sections reported 63 per cent., the three French flash sections reported 16 per cent. and the three American sound sections reported 21 per cent. In a period of two weeks when the advance had been temporarily checked by the enemy the total number of locations was 392 and the percentages were: From three American flash sections, 38 per cent.; from two French flash sections, 8 per cent., and from three American sound sections, 54 per cent. In another and very active sector the figures were: During a period of three days' preparation for an advance, sound locations, 22; flash, 22; balloons, 0; aviation, 0. During a period of sixteen days of rapid advance: Sound, 4; flash, 46; balloons, 30; aviation, 15. During a period of four days of stabilization: Sound, 6; flash, 34; balloons, 13; aviation, 15. These figures are fairly characteristic. During preparations for an advance, both the sound and flash sections are very useful sources of information. During rapid advance the sound rangers do not get into action as often as the flash because of the greater technical difficulties. During this period the major part of the information comes from the aerial observation.

American sound-ranging sections were operating on the front from March, 1918, until the armistice, and always in sufficient numbers to cover the sectors held by American troops except for a portion of the front of the Argonne offensive when the line was moving rapidly. The work of the officers and men of the 74th Engineers engaged in this service was of a very high order, and their untiring watchfulness was often the indirect means of saving the lives of countless of their fellow-soldiers by procuring the information needed to silence the fire of the enemy guns.

THE ABSORPTION OF NUTRIENTS AND ALLIED PHENOMENA IN THE PITCHERS OF THE SARRACENIACEÆ.*

BY

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THE AMERICAN PITCHER PLANTS.

THE *Sarraceniaceæ* or American pitcher plants are bog plants. In this family of plants, the entire leaf has become a pitcher with terminal lid or bilobed flap. The pitcher proper is the hollowed-out midrib of the leaf, in front of which is the wing that represents the fused halves of the blade in *Darlingtonia* and the Sarracenias; the halves are distinct but closely opposed in *Heliamphora*. The lid in *Heliamphora* and the Sarracenias and the bilobed flap in *Darlingtonia* represent a portion of the blade early separated off from the wing below as a result of the hollowing-out of the midrib between the two separated parts of the blade.[1] The developing pitcher and lid form an envelope about a hermetically sealed space—the pitcher cavity. As maturity is reached, the lid and the lips of the pitcher open, and remain in that position permanently.

The pitcher and lid or bilobed flap form a highly developed insect trap. The entire outside epidermis of the pitcher is dotted with nectar glands and forms the "alluring surface." These glands are especially abundant on the "attractive zone," which consists of the inner surface of the lid or bilobed process and the edge of the recurved, thickened rim that surrounds the orifice of the pitcher. In *Heliamphora* and the Sarracenias, the inner surface of the lid is provided with numerous hairs which are directed downward. In *Darlingtonia*, the inner surface of the bilobed flap

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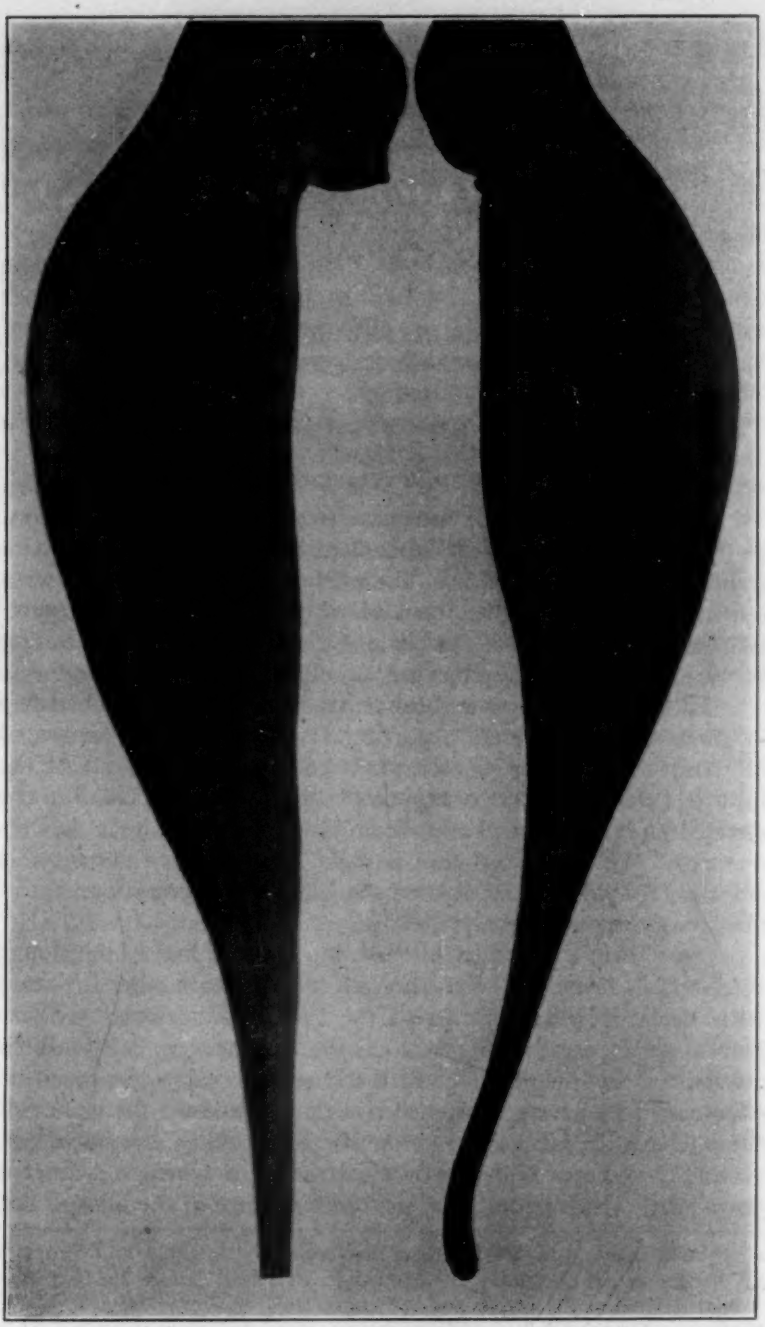


Radiograph of open pitchers of *Sarracenia purpurea* (full size) containing prey. The *liquid* pitcher contents have been removed; the dense shadow represents the mass of captured insects in the lower part of the pitcher; moths, beetles and flies were identified among the captures. Radiograph by Goodspeed.

is provided with similar hairs which are directed toward the mouth of the pitcher. The interior of the pitcher may be divided into two regions. The upper or "conducting" zone has an extremely smooth lining. The lower or "detentive" zone contains long, tapered, downwardly directed hairs.

The pitcher secretes a fluid or pitcher liquor even before the lid and the lips have opened. This secretion varies in amount with the species; it may be merely a studding of minute drops of

Section of open pitcher of *Sarracenia purpurea* according to Macfarlane, showing the wing at the left, the hairy lid, the smooth conducting surface below the rim, the smooth glandular area (characteristic of this species), and the detentive zone with its downward-pointing hairs.

fluid on the lining in the lower portion of the pitcher; or it may fill the pitcher cavity to the depth of several inches. The pitcher liquor increases in volume after the lid and lips have opened, and may be further increased in certain species by rain water or by floods in their native habitat.

Great numbers of insects are attracted by the exuding nectar, probably also by the brilliant color and flower-like shape of the pitcher, and a very perceptible fruity or honey-like fragrance during the period of nectar-exudation. A creeping insect is tempted upward by the nectar on the alluring surface, and finds its way to the attractive surface. A flying insect alights on some

part of the expanded upper portion of the pitcher. The insects sip the nectar, either at the rim of the pitcher, or on the inner surface of the lid or bilobed flap, where their course is directed toward the pitcher cavity by the hairs. In either case, they step upon the smooth conducting surface, which affords no, or a very insecure, foothold, and are precipitated into the pitcher cavity. Their escape is prevented by the hairs of the detentive zone and by the smooth lining of the conducting zone. In some species, the pitcher liquor apparently exerts either a wetting or a stupefying action on the prey. The captured insects then are drowned and undergo digestion.

In this paper the species of the *Sarraceniaceæ* will be enumerated, and their geographical distribution given. Observations on the nectar, and on both the wetting and the digestive power of the pitcher liquor will be reported. A full account will then be given of the studies on absorption, by the pitchers, of compounds introduced into the pitcher cavity. Lastly, the increased secretion of liquor by the pitchers in response to stimulation by introduced substances, and their response to introduced acid and alkali will be described.

CLASSIFICATION AND GEOGRAPHICAL DISTRIBUTION.

The family, *Sarraceniaceæ*, is divided by Macfarlane [1] into three genera which include nine species:

GENUS.	SPECIES.
Heliamphora	*H. nutans*
Darlingtonia	*D. californica*
Sarracenia	*S. minor*
	S. Sledgei
	S. flava
	S. Drummondii
	S. rubra
	S. purpurea
	S. psittacina

The plants of this family have their native habitat in bogs.

The genus *Heliamphora*, with its single species *H. nutans*, has been reported only from Mount Roraima between British Guiana and Venezuela.

The genus *Darlingtonia*, with its single species *D. californica*, occurs only in the mountain bogs of northern California and southwest Oregon.

The genus *Sarracenia* is found in eastern North America. *Sarracenia purpurea* ranges from Labrador, Newfoundland, and Manitoba to the Gulf of Mexico. None of the other six species of this genus occurs north of Virginia or west of Texas; their southern limit is the Gulf of Mexico.

THE NECTAR.

Chemical tests show the presence of sugar in the nectar. Each of the following species was studied separately: *Darlingtonia californica, Sarracenia minor, S. Sledgei, S. flava, S. Drummondii,* and *S. purpurea.* An aqueous solution of the nectar was obtained by washing with distilled water the tops of either 25 or 50 pitchers which were exuding nectar. Each of the six solutions thus prepared reduced Benedict's copper solution, showing the presence of a reducing sugar; each yielded the characteristic crystals of phenylglucosazone with phenylhydrazine; and each gave a distinct crimson solution when heated on the water bath with resorcin and hydrochloric acid (the Seliwanoff reaction for ketose sugars). These reactions would suggest the presence of either fructose or invert sugar in the nectar. The solution of the nectar of *Darlingtonia californica* was lævorotatory; both the optical rotatory power and the copper reducing power of this solution were determined quantitatively; the results indicated the sugar to be *d*-fructose.

ACTION OF THE PITCHER LIQUOR ON LIVING INSECTS.

Mellichamp [2, 3] found that the pitcher liquor of *Sarracenia variolaris* (*S. minor*) exerted an intoxicating, anæsthetic, or narcotic action on house flies, a cockroach, a moth, and a common house spider. His results were confirmed by Watson.[4]

One of us (Jones) has found during the present research that the liquor from both closed and open pitchers of *Sarracenia flava* exerts a wetting or stupefying action on large ants. He has also found that the liquor from both closed and open pitchers of *Darlingtonia californica* does not exert such an action on large ants, bumble bees, or locusts ("grasshoppers"). The wetting or narcotic principle—when present—apparently is not a saponin, for we have obtained a negative result when the hæmolysis test for a saponin was applied to liquor from closed pitchers of *Darlingtonia californica, Sarracenia flava, S. Sledgei,* and *S. Drummondii,* and from open pitchers of *S. flava,* and *S. purpurea.*

PROTEOLYTIC ENZYMES AND BACTERIA OF THE PITCHER LIQUOR.

Zipperer [5] found that the pitcher liquor of *Sarracenia purpurea* dissolved coagulated egg white. He decided that a peptonizing enzyme was secreted by the pitcher and digested the prey.

Fenner [6] concluded that the pitchers of *Sarracenia flava* likewise secrete an enzyme which digests the captured insects.

Batalin,[7] who studied *Darlingtonia californica, Sarracenia variolaris* (*S. minor*), *S. flava*, and *S. purpurea*, speaks of the secretion, by the pitchers of these species, of a solvent for digestion of proteins.

Lambert [8] apparently considered that the pitchers of *Sarracenia purpurea* secrete a proteolytic enzyme similar to pepsin.

Hepburn, St. John, and Jones [9] detected, in the pitcher liquor of *Sarracenia flava*, a proteolytic enzyme which digested carmine fibrin. They also found, in the contents of open pitchers of *S. minor* and *S. flava*, proteolytic bacteria which digested various proteins. These studies have been extended to the other North American pitcher plants *growing in their native habitat*. The results may be summarized briefly. *Darlingtonia californica* apparently does not secrete a proteolytic enzyme, for its pitcher liquor does not digest carmine fibrin in neutral solution, or in the presence of either 0.2 per cent. hydrochloric acid or 0.5 per cent. sodium carbonate. In the genus *Sarracenia*, proteolytic enzymes (proteases) occur in the pitcher liquor of *S. minor, S. Sledgei, S. flava, S. Drummondii, S. rubra*, and *S. purpurea*. The protease in the pitcher liquor of *S. minor* and *S. flava* digests carmine fibrin, best in the presence of a dilute acid (0.2 per cent. hydrochloric); the protease in the pitcher liquor of the other species mentioned digests carmine fibrin, best in an alkaline solution containing 0.5 per cent. or less sodium carbonate. The enzyme usually is present in the liquor before the pitcher has opened. On account of the small size of the pitchers, and the small volume of their contents in *Sarracenia psittacina*, tests for a protease in the pitcher liquor and a bacteriological study of the pitcher contents have not yet been undertaken with this species.

Certain flies of the genus *Sarcophaga* pass their entire larval stage within the *Sarracenia* pitchers, living on the captured insects. These larvæ contain antiproteases;[10] this indicates that the proteases which occur in the pitcher liquor exert a digestive action on proteins present within the pitcher cavity.

In *closed* pitchers, the pitcher cavity and liquor are bacteriologically sterile. This conclusion is based on the bacteriological examination of 44 pitchers, the lids of which had not yet begun to open. Each pitcher was examined separately. These pitchers were obtained from the following species: *Darlingtonia californica, Sarracenia minor, S. Sledgei, S. flava, S. Drummondii,* and *S. purpurea.*

Bacteriological study was also made of the contents of *open* pitchers of the six species just mentioned. All the pitchers used contained captured insects. The contents of 31 pitchers were studied separately, and three examinations were made on composite samples obtained from four or five pitchers; hence 34 samples in all were examined. These pitchers always contained proteolytic bacteria which produced some or all of the following changes when sown on suitable media: Liquefaction of gelatin, coagulation and digestion of the proteins in milk, digestion of coagulated serum albumin (Loeffler's blood serum medium), digestion of coagulated proteins of whole egg (Dorset's egg medium).

ABSORPTION FROM THE PITCHER CAVITY.

Our studies show that the pitchers of the Sarracenias secrete a proteolytic enzyme, and that proteolytic bacteria are present in the pitchers of both *Darlingtonia* and the Sarracenias, in the captured insects and the liquor surrounding them. Therefore at least two means exist for the digestion of the prey. A third possible factor is the autolysis of the insect cadavers, *i.e.*, their digestion by the enzymes of their own tissues. Since digestion of the prey occurs in the pitchers, the question arises whether the pitcher absorbs the products of the digestion, and thereby makes them available for the nutrition of the plant. Several previous investigators have endeavored to determine whether absorption occurs in the pitcher cavity.

Edwards [11] considered that absorption does not occur in the pitchers of *Darlingtonia californica.* He wrote: "I do not attempt to speak authoritatively upon the subject, but I am inclined to think that no process similar to digestion goes on within the plant, but that the fluid mass derived from the decay of the imprisoned insects descends through the tube into the earth, and

is taken up by absorption, through the roots, thus acting as a kind of liquid manure."

Batalin [7] observed certain changes in the pitcher lining of *Darlingtonia californica, Sarracenia variolaris* (*S. minor*), *S. flava,* and *S. purpurea,* after insects had been captured. The pitcher cavity is lined with epidermal cells. The outer layer of the wall of these cells is the cuticular layer, and its outermost portion the cuticula. When the body of a captured insect adhered to the lining of the pitcher, the cuticula and, at times, the entire cuticular layer was cast off from the underlying cells. Batalin concluded that this change in their cell-wall occurred so that the cells might absorb nitrogenous compounds from the captured insects, and thereby satisfy the nitrogen requirement of the plant.

Schimper [12] compared the microscopic structure of pitchers of *Sarracenia purpurea* which contained captured insects or into which meat had been introduced, with that of pitchers of the same species which had been starved by plugging the mouth with tissue paper as soon as the lid had opened. The "nourished" and the "starved" pitchers differed markedly with respect to the histological structure of the protoplasm in the epidermal cells in the bottom portion of the pitcher and, to a lesser degree, in the cells of the adjacent subepidermal layer. This difference in structure was taken as evidence of absorption.

The experiments of Fenner [6] were made on *Sarracenia flava.* He noted a typical aggregation and turbidity of the contents of the cells in the bottommost zone when the pitcher contained freshly captured insects. This was most marked in the innermost layer of the pitcher-wall. A large number of dark masses occurred in the second layer of cells of the pitcher lining in this zone. These changes in the cell contents were attributed to the absorption of organic substances. When water or meat juice was introduced into a pitcher, it decreased in volume after a time, even though the mouth of the pitcher was closed with a cotton plug to prevent evaporation; therefore absorption occurred.

Goebel [13] conducted experiments on *Darlingtonia californica, Sarracenia illustrata* (a hybrid between *S. flava* and *S. purpurea*), *S. Drummondii,* and *S. purpurea.* A definite volume of water or of *one* of the following solutions was introduced into each pitcher studied: 1 per cent. formic acid, 5 per cent. peptone, dilute neutral meat infusion. In some of the experiments a minute frag-

ment of meat was introduced with the water; fibrin was introduced with the formic acid solution. Precautions were taken to prevent evaporation. A marked decrease in the volume of the pitcher contents occurred in two days, and was taken as evidence of absorption.

Lambert [8] tested the absorptive power of the pitchers of *Sarracenia purpurea* by means of certain dyes. Several drops of a solution of a crystalloid stain, such as methylene blue or fuchsin, were added to the pitcher contents; and the pitcher was cut open approximately two hours later. Staining had occurred only in the wall of the bottom region, also called the absorptive zone or "stomach." The blue or red color, according to the stain used, was found only in the internal epidermis and one or two layers of subepidermal "digestive cells" which are characteristic of this zone. A highly concentrated solution of methylene blue, introduced into living pitchers, produced the same result whether its period of action was several hours or an entire week. The epidermis and digestive cells alone were stained. The stain was absorbed, then localized; and a limit was thus placed on the total amount of absorption. Lambert concluded that the prey is digested with the production of peptones, which are absorbed by the epidermal cells and localized by the digestive cells.

Higley [14] applied the methods of quantitative chemical analysis in studying absorption from the pitcher cavity in *Sarracenia purpurea*. He made several sets of experiments. In each set he used two pitchers of the same age and size, growing on the same plant, and containing the same volume of liquor and approximately the same amount of insect remains; the pitchers selected contained but few captured insects. A quantitative determination of the "organic ammonia" was immediately made on the fluid from one of the pitchers. The other pitcher was protected so that rain could not enter, and left thus for one week; then the "organic ammonia" content of its fluid was determined, and compared with that of the first pitcher. "The fluid showed a decided decrease in each case, from the amount found in the one used in comparison. Though these analyses were perhaps quite far from sure in every detail, yet the average difference on comparison, *viz.*, sixty parts in one hundred, would indicate quite rapid absorption, for such an amount could not possibly be removed in any other way."

Darwin [15] cites Burnett [16] as stating that "*Sarraceniæ*, if kept from the access of flies, are said to be less flourishing in their growth than when each pouch is truly a sarcophagus." This observation would indicate that these plants absorb, and are nourished by, products formed in the pitchers from the captured insects.

To sum up, previous investigators have given as evidence of absorption: (1) histological changes in either the cell wall or cell contents of the pitcher lining; (2) a decrease in the volume of solutions introduced into the pitcher cavity; (3) absorption of stains, and (4) changes in the "organic ammonia" content of the pitcher liquor.

A decrease in the volume of an introduced solution indicates absorption of water, but not necessarily of the solute or dissolved substance. Apparently no one, as yet, has introduced a *known weight* of a nutrient compound into a pitcher of any of the North American pitcher plants, and studied its absorption quantitatively. However, one such experiment has been made by Clautriau,[17] who demonstrated by this means the absorption of the proteins of egg-white by a pitcher of *Nepenthes Mastersiana*, which belongs to the *Nepenthaceæ* or oriental family of pitcher plants.

ABSORPTION TESTS.

Absorption tests have been made in the field on the following species and at the following places:

Darlingtonia californica at Keddie, Plumas County, California.
Sarracenia Sledgei at Theodore, Mobile County, Alabama.
Sarracenia flava at De Funiak Springs, Walton County, Florida; and at Summerville, Berkeley County, South Carolina.
Sarracenia Drummondii at Theodore, Mobile County, Alabama.
Sarracenia purpurea in Tolland County, Connecticut.

Vigorous plants of *Sarracenia purpurea* were obtained at Whitings, Ocean County, New Jersey, and used in laboratory experiments on absorption; they were planted in sphagnum moss; and the pots were kept filled with water. The plants were kept in the laboratory for several weeks; they retained their vigor and produced new pitchers. While our experiments were conducted on freshly gathered plants, we have maintained plants in the laboratory for as long as five months.

A separate series of experiments was made concerning the absorption from the pitcher cavity of *each* of the following:

1. Water.
2. Nitrogenous compounds—chiefly organic.
3. Organic nitrogenous compounds in the presence of a "buffer."
4. Phosphates.
5. The lithium ion.

Absorption of water was studied by observation of the changes in the volume of the pitcher contents after introduction of a definite volume of water.

Absorption of nitrogenous compounds and of phosphates was measured by the retention of nitrogen or phosphates by the plant. For the study of nitrogen retention, a solution containing a known weight of a nitrogenous compound was introduced into a pitcher; the fluid remaining in the pitcher was withdrawn at the end of a given time; and the amount of nitrogen present in it was determined. The difference between this weight and the weight of nitrogen introduced was the weight of nitrogen absorbed by the pitcher and retained by the plant. Retention of phosphates was studied in exactly the same manner, using a solution of phosphates, and making determinations of phosphoric oxide.

All the nitrogen compounds used in these experiments were non-volatile, hence could not escape from the pitcher. In one series of tests of nitrogen absorption, a "buffer" solution was added to the pitcher contents to prevent the escape of any volatile nitrogenous compounds, possibly formed by reactions occurring in the pitcher cavity.

In the experiments on the absorption of the lithium ion, lithium, which does not normally occur in the tissues of the pitcher, was found in those tissues after its absorption from the pitcher contents to which it had been added.

ABSORPTION OF WATER.

Technic.—The average volume of the true pitcher liquor (*not* diluted by rain) was determined for certain species by actual measurement of the amount in large, vigorous pitchers. The upper portions of the pitcher were clipped off with scissors until the pitcher liquor was within reach of a plain pipette, the lower portion of which was of fine bore. After each portion of liquor was removed with the pipette, another section of the pitcher was cut away; and this procedure was repeated until all the liquor had been collected from the pitcher. The total liquid contents of a

definite number of pitchers were thus collected in a stoppered vial; the total volume was then determined in a narrow graduated cylinder; and the average volume was calculated. This technic was found most satisfactory for field work in the bogs which are the native habitat of these plants. The average volume, the number of lots of pitchers studied and the total number of pitchers used in obtaining the average are given in Table I.

TABLE I.

Average Volume of Liquor in the Pitchers of Certain Sarraceniaceæ.

Genus and species.	Condition of pitchers.	Number of lots measured.	Total number of pitchers used.	Average volume of pitcher liquor.
				c.c.
Darlingtonia californica....	Closed.....	10	353	1.08
Darlingtonia californica....	Open.....	5	161	2.80
Sarracenia Sledgei.....	Open.....	3	74	0.38
Sarracenia flava.....	Closed.....	6	566	0.66
Sarracenia flava.....	Open.....	4	160	1.50
Sarracenia Drummondii...	Open.....	4	138	0.58

Water was introduced into pitchers of the same size and vigor as those used in the determination of the average volume of the pitcher liquor. With *open* pitchers, a definite volume of water was poured from a narrow graduated cylinder into the mouth of the pitcher; the top of the pitcher was folded over; and one or more pins were passed through the double fold. The pitchers were thus sealed, but were not injured; none of the tissues withered, not even the folded-over tops. Entrance of rain water and of insects was prevented. Identification labels of paper were inserted in the double fold, and were held in place by the pins. With *closed* pitchers, the top of the pitcher was cut off just beneath the lips or pitcher rim; a definite volume of water was poured into the pitcher cavity from a narrow graduated cylinder; and the upper portion of the pitcher was folded over and sealed as with open pitchers; the pitchers remained green and vigorous.

After the lapse of a definite period of time, the contents of these pitchers were collected, and their average volume determined. The technic was that used in the determination of the average volume of pitcher liquor as described above.

Results.—These experiments are summarized in Table II. The "shrinkage" was obtained as follows: From the sum of

the volume of water introduced plus the average volume of pitcher liquor was subtracted the average volume of the pitcher contents at the end of the experiment. For instance, open pitchers of *Sarracenia Drummondii* contain, on the average, 0.58 c.c. of pitcher liquor; each pitcher received 5.00 c.c. of water; and the average volume of the pitcher contents at the end of the experiment was 3.60 c.c. The shrinkage was $0.58 + 5.00 - 3.60 = 1.98$ c.c.

The pitcher contents of these species were so protected from rapid evaporation that the shrinkage in volume must be considered as due to absorption by the pitchers. The results indicate that but little, if any, absorption occurred in closed pitchers of

TABLE II.

Absorption of Water from the Pitcher Cavity in Certain Sarraceniaceæ.

Species.	Condition of pitchers.	Number of pitchers used in experiment.	Volume of water introduced into each pitcher.	Period of absorption.	Average volume of pitcher contents at end of experiment.	Shrinkage (allowance made for average volume of pitcher liquor).
			c.c.	*hours*	*c.c.*	*c.c.*
Darlingtonia californica	Closed	12	3.00	24	4.16	none
Darlingtonia californica	Closed	5	3.00	72	3.94	0.14
Darlingtonia californica	Closed	5	3.00	144	3.94	0.14
Darlingtonia californica	Just open	5	3.00	72	5.16	0.64
Darlingtonia californica	Just open	4	3.00	144	4.37	1.43
Sarracenia Sledgei	Open	20	5.00	7	2.95	2.43
Sarracenia flava	Closed	4	10.00	48	6.95	3.71
Sarracenia flava	Open	4	10.00	48	6.80	4.70
Sarracenia Drummondii	Open	15	5.00	7	3.60	1.98

Darlingtonia californica; in open pitchers of this species, water was absorbed, and the volume absorbed increased with the period of absorption. The volume of water absorbed was greater in open than in closed pitchers of *Sarracenia flava,* other factors being equal. Absorption of water also occurred in open pitchers of *S. Sledgei* and *S. Drummondii.*

In a laboratory experiment, seven young, vigorous, fully opened pitchers of *Sarracenia purpurea,* approximately equal in size, were freed from insect remains by thorough washing with distilled water, which was then completely removed with a pipette. Ten (10.00) c.c. of distilled water were introduced from a pipette into each *empty* pitcher, which was then closed with a tightly fitting cotton plug. Ten days later, the water was removed from

each pitcher with a serological pipette. The volumes obtained from the individual pitchers were 0.00, 6.00, 7.30, 8.10, 7.90, 6.95, and 6.10 c.c., respectively, the average volume 6.05 c.c. This experiment was repeated with six pitchers of approximately the

Mature plant of *Darlingtonia californica*, showing the twisted pitcher, and expanded hood with the orifice below, the translucent window-like spots, and the pendant bilobed flap. Photographed in Plumas County, California, where the pitchers commonly attain a height of 20 to 30 inches.

same size, each pitcher receiving 10.00 c.c. of distilled water; twenty-one days later, four pitchers contained no liquid, the other two contained 1.10 and 6.90 c.c., respectively; therefore the average volume remaining in the pitchers was 1.33 c.c. The average shrinkage in volume increased with the time, *i.e.*, was greater in twenty-one days than in ten days. The decrease in volume of the

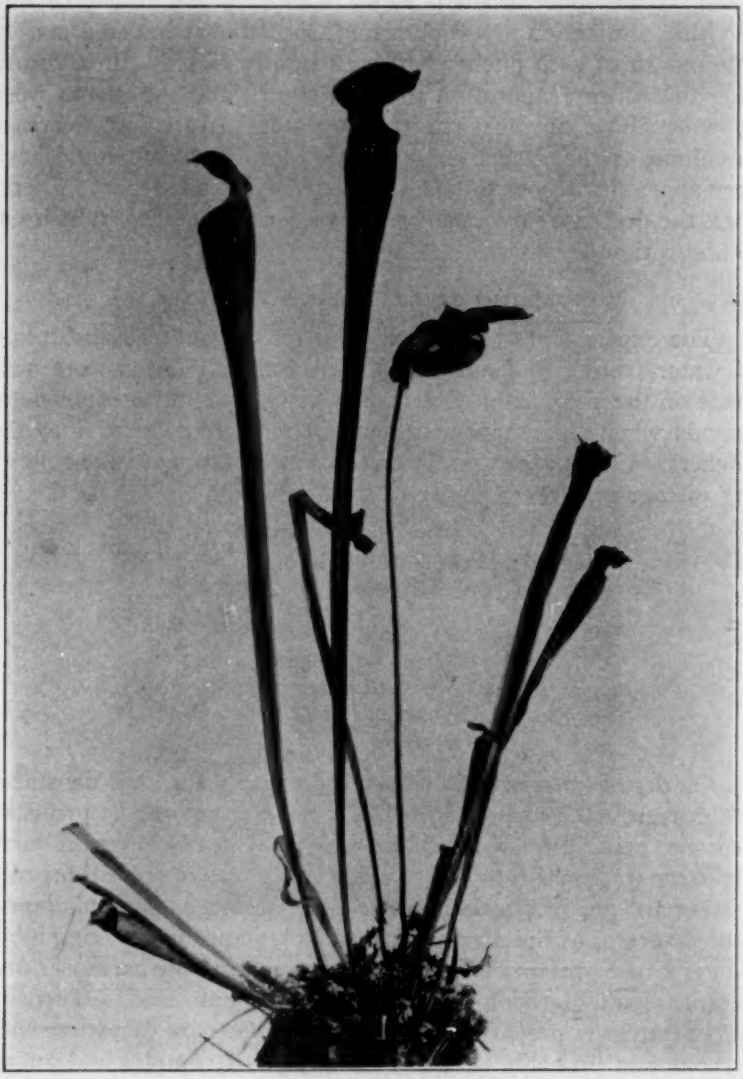
water in the short broad pitchers of this species might be due to either absorption or evaporation, or to their combined action. The mouth of each pitcher had been tightly closed with a cotton plug to reduce evaporation to a minimum; and the plants were growing above an open surface of water. Moreover, decrease in volume of the pitcher contents due to evaporation would have been approximately equal in all the pitchers of each series. Therefore, the decrease in volume must have been due, in part at least, to absorption of water.

ABSORPTION OF NITROGENOUS COMPOUNDS.

The experiments just described demonstrated the absorption of water from the pitcher cavity by the plant. Tests were next made on the absorption of various non-volatile nitrogenous compounds when their aqueous solutions were introduced into the pitchers. Each nutrient solution contained but *one* of the following nitrogenous compounds:

Ammonium chloride
Ammonium tartrate
Acetamide
Urea
Asparagin
Glycocoll
Trypsinized peptone
Peptone (Witte)
Egg albumin

On digestion, a protein passes successively through the stages of protean, meta-protein, primary proteose, secondary proteose, peptone, peptides, and amino acids. Enzymes like pepsin carry digestion to the peptone stage, while enzymes like trypsin proceed farther and produce amino acids. The nutrient compounds represented several of these groups of proteolytic products. Egg albumin is a true protein; Witte peptone represents the proteoses and peptones; and glycocoll and asparagin are amino acids. Trypsinized peptone is prepared from Witte peptone by digestion with trypsin, and probably is chiefly a mixture of peptides and amino acids. Closely related to the amino acids are the acid amides such as acetamide and urea (the diamide of carbonic acid), and the ammonium salts such as ammonium chloride and ammonium tartrate. The pitchers, therefore, received nitrogenous compounds of all stages of molecular complexity from the simple



Mature plant of *Sarracenia Sledgei*, showing recently opened pitchers, the flower from which the petals have fallen, and the shrivelled pitchers of the preceding season. Photographed at Biloxi, Mississippi, where the pitchers commonly attain a height of 16 to 24 inches.

inorganic ammonium chloride and the simple organic ammonium tartrate to the highly complex egg albumin.

Each nutrient solution was prepared immediately prior to use, by dissolving the finely divided compound in distilled water, and

Group of *Sarracenia flava*, showing open pitchers, photographed in midsummer at Southern Pines, North Carolina. The pitchers of this species attain a maximum height of nearly 40 inches, though commonly between 20 and 30 inches tall.

filtering if necessary. Heat was used only in the preparation of the solution of Witte peptone; the filtered solution was cooled to atmospheric temperature prior to use. The solution of trypsinized peptone was made according to the directions of Rivas.[21] As a rule, the solutions were about tenth normal for nitrogen, *i.e.*,

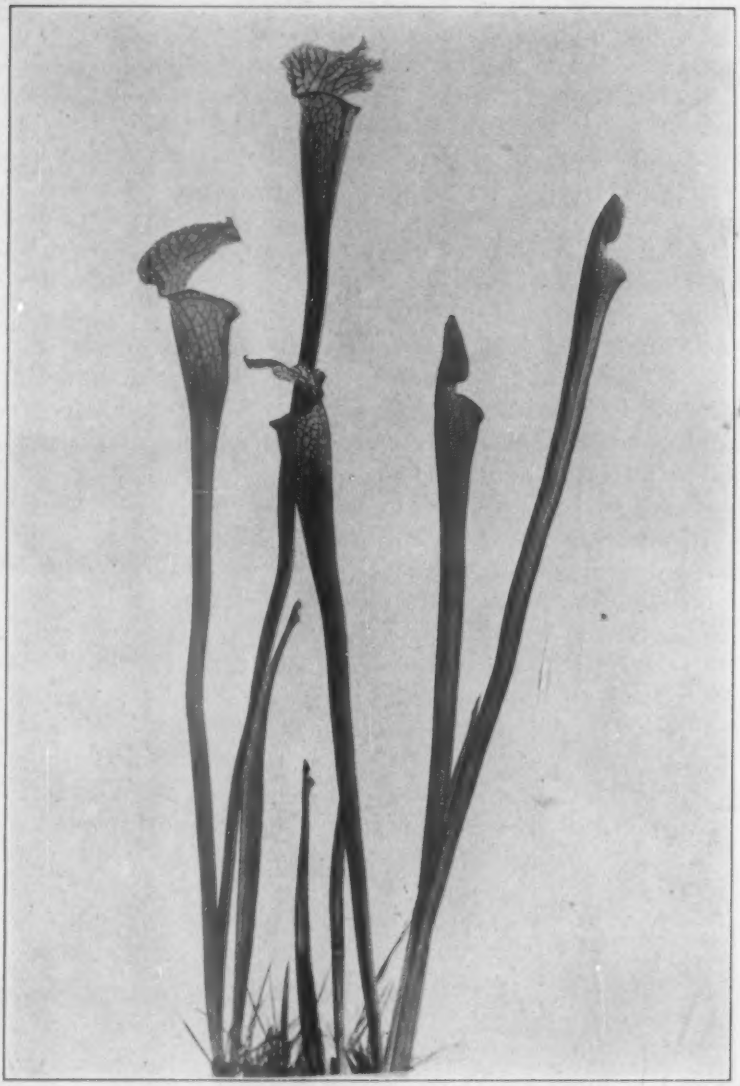
contained approximately 1.4 grams nitrogen per litre. A definite volume of a nutrient solution was always introduced into a pitcher; the same volume of the same solution was used for the determination of the exact nitrogen content of the solution by the Gunning modification of the Kjeldahl method.

Technic.—The procedure with the tall slender pitchers of *Sarracenia Sledgei, S. flava,* and *S. Drummondii* was somewhat different from that with the short broad pitchers of *S. purpurea.*

In plants of the first three species, the shape and size of the pitcher made it impossible to wash out the pitcher cavity and remove the wash water before introduction of the nutrient peptone solution. Therefore, the peptone solution was introduced directly into the untreated pitcher cavity. Pitchers of three types were used: closed, open, and plugged. The technic for *closed* pitchers and *open* pitchers was that used for such pitchers in the experiments on the absorption of water; however, a peptone solution was substituted for the water. *Plugged* pitchers were pitchers which, in age and development, were open and active, but had been kept free from insect captures. Closed pitchers, which were about to open, were selected; the top of each pitcher was folded over, and one or more pins were passed through the double fold; a paper identification tag was placed in the fold. The pitcher, thus sealed, was not injured, but continued to grow, and to expand its top even above the fold; withering of the tissues never occurred. After the lapse of seven or more days, the pitcher was used in an absorption experiment; the procedure was that followed with closed pitchers.

Three days after introduction of the peptone solution, the liquid remaining in the pitcher was collected as in the experiments on absorption of water. At times, its volume was measured in a narrow graduated cylinder. The liquid was then preserved with trikresol. It and the sample of the peptone solution (likewise preserved with trikresol) were placed in stoppered vials, and brought to Philadelphia for determination of the nitrogen content.

The open pitchers of *Sarracenia purpurea* were gently flushed with distilled water from a wash bottle; the macerated mass of insects was scraped from the pitcher walls with a fine loop of platinum wire; the pitcher contents were then removed with a pipette. This process of washing was repeated several times until the pitchers were as free as possible from insect remains. A



Plant of *Sarracenia Drummondii*, showing fully open pitchers, and younger pitchers with closed lids and lips. Photographed in Mobile County, Alabama, where the mature pitchers commonly attain a height of 18 to 28 inches.

definite volume—usually, though not invariably, 10.00 c.c.—of a nutrient solution was introduced by means of a pipette into the *empty* pitcher, and the mouth of the pitcher was tightly closed with a cotton plug. From three to twelve days later, the plug was removed; it was always dry, and not soiled by the pitcher contents. The liquid in the pitcher was drawn up into a serological pipette; its volume was noted; and it was transferred to a Kjeldahl flask. The interior of the pitcher was washed with several successive portions of distilled water; these were transferred in turn by means of the pipette to the Kjeldahl flask; and the nitrogen content of the combined liquid and washings, which had a total volume of approximately 250 c.c., was determined by the Gunning method. In the field experiments on this species, a measured volume of the nutrient solution was poured into the pitcher from a narrow graduated cylinder. The sample of the nutrient solution, and the combined liquid and washings from each pitcher were placed in a separate stoppered vial, preserved with trikresol, and brought to Philadelphia for analysis.

All determinations of nitrogen were made by the Gunning modification of the Kjeldahl method. If in a vial, the liquid was transferred to a Kjeldahl flask; and the vial was washed with several successive portions of distilled water which were transferred to the same flask. If necessary, the liquid from the open pitchers of *Sarracenia flava* was filtered to remove solid insect remains, then was analyzed. A crystal of cupric sulphate the size of a small grain of rice, 10 grams of potassium sulphate, and 25 c.c. of concentrated sulphuric acid were added to the contents of the flask, which were then heated until all the water had evaporated. The determination of nitrogen was then carried out in the usual way. Tenth normal solutions of sulphuric acid and sodium hydroxide were used for titration of the ammonia, using methyl red (orthocarboxybenzeneazodimethylaniline) as an indicator.

Action of the Nutrient Solutions on the Pitchers.—Of all the nutrient solutions used, only that of ammonium chloride exerted any injurious action on the containing pitchers. On the third day after introduction of the ammonium chloride solution, the pitchers were still normal. By the sixth day, the tip of the lid had withered; and by the tenth day the withered region included the

entire lid and the rim of the pitcher. On the other hand, ammonium tartrate solution had no injurious action on the pitchers.

Toluene was introduced into the pitcher with the peptone solution in two experiments recorded at the bottom of Table III. The pitchers withered above the level of their contents, but were not injured below that level.

Tabulation of the Results.—Details of the experiments are given in Table III. Since the weight of nitrogen, and not the weight of the nutrient compound, was determined, weights have been reported as grams of nitrogen. The analysis of the nutrient solution showed the weight of nitrogen introduced; analysis of the liquid remaining in the pitcher several days later gave the weight of nitrogen recovered; the former weight minus the latter weight equalled the weight of nitrogen absorbed. The weight of nitrogen absorbed was then calculated as per cent. of the weight of nitrogen introduced.

The volume of solution introduced and that of the liquid remaining in the pitcher at the end of the experiment are given; the difference between the two is the decrease in volume, which has also been calculated as per cent. of the volume introduced. In the experiments on *Sarracenia purpurea,* this per cent. is probably an index to the absorption of the water.

Absorption by the Southern Species.—Plugged pitchers of both *Sarracenia Sledgei* and *S. Drummondii,* and both closed and open pitchers of *S. flava* always showed a marked absorption of peptone in three days; some pitchers absorbed over 40 per cent. of the introduced peptone.

In the calculation of the absorption, the nitrogen content of the pitcher liquor itself and, in open pitchers, the presence of soluble nitrogenous compounds, derived from the prey, have been neglected. They would increase both the weight of nitrogen present at the beginning of the experiment and the weight of nitrogen absorbed, by exactly the same amount, and would therefore increase the value for the per cent. of nitrogen absorbed. The influence of nitrogenous compounds derived from the prey would depend on the size and number of captured insects.

The nitrogen content of the pitcher liquor is negligible. It amounted to 0.000036 gram nitrogen per 1 c.c. of liquor in a composite sample obtained from 100 closed pitchers of *Sarracenia flava.* A composite sample from 50 open pitchers of this

species contained 0.000060 gram nitrogen per 1 c.c.; another composite sample, also from open pitchers of this species, contained 0.000050 gram nitrogen per 1 c.c., giving an average of 0.000055 gram per 1 c.c. Each sample used for an analysis had a volume of either 25 or 50 c.c. The average volume of the pitcher liquor is 0.66 c.c. in closed pitchers and 1.50 c.c. in open pitchers of *S. flava* (Table I), 0.38 c.c. in plugged pitchers of *S. Sledgei* (average of 31 pitchers), and 0.66 c.c. in plugged pitchers of *S. Drummondii* (average of 20 pitchers). In the entire series of experiments, the influence exerted by the nitrogen content of the pitcher liquor would be greatest in the experiment on four open pitchers of *S. flava*, and would change the per cent. of nitrogen absorbed from 40.49 to 40.73, an increase of about one-quarter per cent.

The liquor in the plugged pitchers may be considered to have the same nitrogen content as that in the closed pitchers of *S. flava*. On account of the smaller volume of the pitcher liquor and its lower nitrogen content, the increase in the per cent. of nitrogen absorbed, due to the nitrogen content of the liquor, would be considerably less in both closed pitchers and plugged pitchers than in open pitchers.

The changes in volume observed in the contents of the pitchers of *Sarracenia flava* may be recalculated, taking into consideration the liquor present in the pitcher at the beginning of each experiment and using the average volume of pitcher liquor as given in Table I. The recalculated percentage decrease in volume is given below; it may be considered to represent the absorption of water. For convenience, the per cent. of introduced nitrogen absorbed is repeated.

	Per cent. of introduced nitrogen absorbed.	Percentage decrease in volume.
1 Closed Pitcher	30.79	37.15
3 Closed Pitchers	42.08	39.97
1 Open Pitcher	36.84	35.65
4 Open Pitchers	40.49	40.79

The results indicate that absorption of the solute (peptone) and of the solvent (water) were not strictly parallel, and did not proceed at exactly the same rate.

Absorption by Sarracenia purpurea.—The experiments on small, poorly developed pitchers of *Sarracenia purpurea* were

made in the field in Tolland County, Connecticut. The results showed that this species absorbs ammonium tartrate, acetamide, urea, and peptone from their aqueous solutions when these solutions are introduced into the pitcher cavity.

The experiments on large vigorous pitchers of *Sarracenia purpurea* were made in the laboratory; the pitchers had recently opened. Aqueous solutions of nine different nutrient nitrogenous substances were introduced into the pitchers; and all nine substances were absorbed to a marked degree. While the "individual difference" of each pitcher entered into each test and was beyond control, the results, as a whole, uniformly had the same trend, and support the following conclusions. The absorption of nitrogenous compounds was progressive, since the per cent. of introduced nitrogen absorbed increased with the time; from 50 to 90 per cent. or more of the nutrient compound was usually absorbed in twelve days. The rate of absorption was generally greatest during the first three or four days. With the exception of the experiments on egg albumin, the per cent. of the introduced nitrogenous compound absorbed in a given time was always greater than the percentage decrease in the volume of the pitcher contents; *i.e.*, the dissolved nutrient was absorbed more rapidly than the water. This conclusion, of necessity, holds true even if part of the water was lost by evaporation.

Absorption of water from the solution occurred. The experiments on ammonium tartrate, acetamide, urea, and asparagin were begun on the same day with pitchers of approximately the same size and with the same volume of nutrient solution. They ended twelve days later. During that time, the decrease in volume of the pitcher contents varied from 22.0 to 60.5 per cent. in different experiments, while it would have been approximately equal in all experiments if due entirely to evaporation.

Egg albumin was absorbed less rapidly than the simpler nitrogenous compounds. This indicates that possibly the complex protein was digested into simpler compounds prior to absorption.

Ammonium chloride was absorbed less rapidly than ammonium tartrate. The absorption of peptone was decreased when toluene was added to the pitcher contents. The decreased absorption was possibly due to the toxic action of the ammonium chloride and the toluene on the pitchers.

TABLE III.

Absorption of Nitrogenous Compounds from the Pitchers of Species of Sarracenia

Species.	Description of pitchers.	Number of pitchers	Nitrogen compound introduced.	Period of absorption, days.	Nitrogen absorption.				Volume changes.			
					Weight, in grams, of nitrogen.			Per cent. of introduced nitrogen absorbed.	Volume of nutrient solution introduced.	Volume of solution recovered.	Decrease in volume.	Decrease in volume calculated as per cent. of volume introduced.
					Introduced.	Recovered.	Absorbed.					
									c.c.	c.c.	c.c.	
Sarracenia Sledgei....	Plugged	1	Peptone	3	0.01422	0.00792	0.00630	44.30	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01366	0.00960	0.00406	29.72	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01450	0.01044	0.00406	28.00	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00651	0.00393	37.64	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00609	0.00435	41.67	.....	.....	.....	.....
Sarracenia flava.....	Closed	1	Peptone	3	0.01387	0.00960	0.00427	30.79	10.00	6.70	3.30	33.00
	Closed	3	Peptone	3	0.04644	0.02690	0.01954	42.08	40.00	25.20	14.80	37.00
	Open	1	Peptone	3	0.01387	0.00876	0.00511	36.84	10.00	7.40	2.60	26.00
	Open	4	Peptone	3	0.08133	0.04840	0.03293	40.49	70.00	45.00	25.00	35.71
Sarracenia Drummondii	Plugged	1	Peptone	3	0.01142	0.01030	0.00112	9.81	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01478	0.00932	0.00546	36.94	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01478	0.00778	0.00700	47.36	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00658	0.00386	36.97	.....	.....	.....	.....
	Plugged	1	Peptone	3	0.01044	0.00630	0.00414	39.66	.....	.....	.....	.....
Sarracenia purpurea.. (small, poorly developed pitchers)	Open	1	Ammonium tartrate	7	0.01352	0.00960	0.00392	28.99	.....	.....	.....	.....
	Open	1	Acetamide	7	0.01464	0.00736	0.00728	49.73	.....	.....	.....	.....
	Open	1	Urea	7	0.01436	0.00595	0.00841	58.57	.....	.....	.....	.....
	Open	1	Peptone	7	0.01415	0.00890	0.00525	37.10	.....	.....	.....	.....
Sarracenia purpurea (large, vigorous pitchers)	Open	1	Ammonium chloride	3	0.01499	0.01261	0.00238	15.88	.....	.....	.....	.....
	Open	1	Ammonium chloride	6	0.01499	0.01156	0.00343	22.88	.....	.....	.....	.....
	Open	1	Ammonium chloride	10	0.01499	0.01030	0.00469	31.29	.....	.....	.....	.....
	Open	1	Ammonium tartrate	4	0.01331	0.00953	0.00378	28.40	.....	.....	.....	.....
	Open	1	Ammonium tartrate	7	0.01331	0.00883	0.00448	33.66	.....	.....	.....	.....
	Open	1	Ammonium tartrate	12	0.01331	0.00658	0.00673	50.56	10.00	6.95	3.05	30.50
	Open	1	Acetamide	4	0.01464	0.00602	0.00862	58.88	.....	.....	.....	.....
	Open	1	Acetamide	7	0.01464	0.00329	0.01135	77.53	10.00	8.60	1.40	14.00
	Open	1	Acetamide	12	0.01464	0.00056	0.01408	96.17	10.00	3.95	6.05	60.50
	Open	1	Urea	4	0.01317	0.00616	0.00701	53.23	.....	.....	.....	.....
	Open	1	Urea	7	0.01317	0.00581	0.00736	55.88	10.00	9.50	0.50	5.00

Open	1	Urea	12	0.01317	0.00336	0.00981	74.49	10.00	7.80	2.20	22.00
Open	1	Asparagin	4	0.00588	0.00266	0.00322	54.76	.....	.....	.....	.....
Open	1	Asparagin	7	0.01198	0.00462	0.00736	61.44	10.00	8.00	2.00	20.00
Open	1	Asparagin	12	0.01198	0.00182	0.01016	84.81	10.00	6.30	3.70	37.00
Open	1	Glycocoll	4	0.01422	0.01121	0.00301	21.17	.....	.....	.....	.....
Open	1	Glycocoll	7	0.01422	0.00981	0.00441	31.01	10.00	8.35	1.65	16.50
Open	1	Glycocoll	12	0.01422	0.00217	0.01205	84.74	.....	.....	.....	.....
Open	1	Trypsinized peptone	3	0.01786	0.01170	0.00616	34.49	10.00	9.60	0.40	4.00
Open	1	Trypsinized peptone	7	0.01786	0.00778	0.01008	56.44	10.00	9.15	0.85	8.50
Open	1	Trypsinized peptone	12	0.01786	0.00546	0.01240	69.43	10.00	8.60	1.40	14.00
Open	1	Peptone	3	0.07061	0.06634	0.00427	6.05	25.00	23.50	1.50	6.00
Open	1	Peptone	6	0.07061	0.05842	0.01219	17.26	25.00	22.50	2.50	10.00
Open	1	Egg albumin	4	0.01765	0.01429	0.00336	19.04	10.00	8.30	1.70	17.00
Open	1	Egg albumin	7	0.01765	0.01205	0.00560	31.73	10.00	5.80	4.20	42.00
Open	1	Egg albumin	12	0.01765	0.00820	0.00945	53.54	10.00	1.90	8.10	81.00
Open	1	Peptone *	3	0.07061	0.06760	0.00301	4.26	25.00	24.50	0.50	2.00
Open	1	Peptone *	6	0.07061	0.06262	0.00799	11.32	25.00	23.00	2.00	8.00

* In these experiments, toluene was added to the contents of the pitcher.

ABSORPTION OF ORGANIC NITROGENOUS COMPOUNDS IN THE PRESENCE OF A "BUFFER."

The objection might be raised that the nitrogen, reported in Table III as absorbed, was actually converted into volatile nitrogenous compounds which escaped from the pitcher. While open pitchers of all the species used in the absorption tests have been found by us to contain bacteria which, in the Petri dish, act on simple nitrogenous compounds (glycocoll, asparagin, acetamide, urea, ammonium lactate, ammonium tartrate) with the production in the medium of a reaction alkaline to rosolic acid, and occasionally with the production of an odor of ammonia or amines, nevertheless, such an odor was never noted in the pitcher contents when they were removed for analysis at the end of an absorption test.

Reference to Table III shows that, in the presence of toluene, a bactericide, peptone was absorbed.

Additional laboratory tests on absorption were conducted, in which a "buffer" was introduced into pitchers of *Sarracenia purpurea* with the nutrient solution. Any volatile bases, formed from the nutrient nitrogenous compound by bacterial action, would be retained by the buffer, and could not escape from the pitcher.

The buffer used was an aqueous solution containing 0.4 gram monopotassium phosphate (KH_2PO_4) and 0.6 gram dipotassium phosphate (K_2HPO_4) in each 10 c.c.; a buffer solution containing these two phosphates in this ratio has been used in urinalysis to neutralize the ammonium carbonate formed by cleavage of urea by the enzyme urease.[22]

Technic.—The procedure in these experiments was exactly the same as in those on the absorption of nitrogenous compounds by *Sarracenia purpurea* described in the preceding section. However, 10.00 c.c. of the buffer solution were introduced into each pitcher at the same time as the 10.00 c.c. of the solution of the nutrient nitrogenous compound. Likewise 10.00 c.c. of the buffer solution were added to each sample of the nutrient solution used for the determination of the exact weight of nitrogen introduced.

In those experiments in which the period of absorption was seven days, the technic was modified somewhat. The pitcher was cut from the plant at its base; its exterior was cleansed with

a stream of distilled water from a wash bottle; and the cotton plug was removed from the mouth of the pitcher; it was always dry and unsoiled. The bottom part of the pitcher was cut off at the very beginning of the pitcher cavity; and the pitcher contents and subsequent washings were caught in a beaker, and passed in turn through a filter into a Kjeldahl flask. In this manner, all chances for retention of the solution of the nitrogenous compound in the narrow, bottom region of the pitcher cavity were entirely eliminated.

Results.—All four compounds—urea, acetamide, asparagin, and peptone—were absorbed in the presence of the buffer. The per cent. of introduced nitrogen absorbed usually increased with the period of absorption. Although approximately the same weight of a given compound was introduced into the pitchers in both series of experiments, the per cent. absorbed in a given time was usually less in the presence of the buffer (Table IV) than

TABLE IV.

Absorption of Organic Nitrogenous Compounds by Individual Open Pitchers of Sarracenia purpurea in the Presence of a Buffer.

Nitrogenous compound.	Period of absorption, days.	Weight, in grams, of nitrogen.			Per cent. of introduced nitrogen absorbed.
		Introduced.	Recovered.	Absorbed.	
Acetamide	4	0.01548	0.00953	0.00595	38.44
Acetamide	7	0.01548	0.00077	0.01471	95.03
Urea	4	0.01471	0.01093	0.00378	25.70
Urea	7	0.01471	0.01247	0.00224	15.23
Asparagin	4	0.01422	0.00981	0.00441	31.01
Asparagin	7	0.01422	0.00637	0.00785	55.20
Peptone	3	0.01569	0.01037	0.00532	33.91
Peptone	15	0.01569	0.00743	0.00826	52.64

in its absence (Table III). In this connection, it should be noted that the plants used in the experiments with the buffer were procured several months later than those used in the experiments on the absorption of nitrogenous compounds and the absorption of phosphates, and possibly were less active though still vigorous.

In the presence of the buffer, the pitcher contents increased in volume, while they decreased in nitrogen content. The initial volume was 20 c.c. At the end of four days, the contents of

three pitchers were withdrawn for analysis, and had the following volume:

Pitcher containing acetamide	25 c.c.
Pitcher containing urea	24 c.c.
Pitcher containing asparagin	24 c.c.

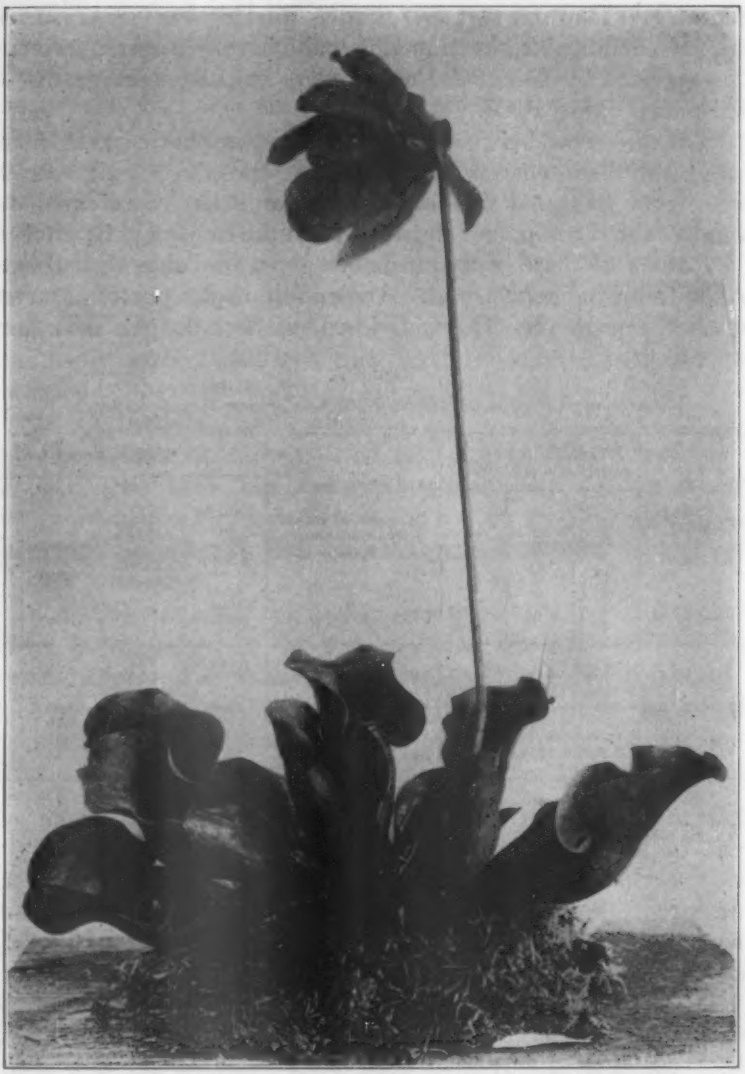
The increase in volume therefore ranged from 20 to 25 per cent.

ABSORPTION OF PHOSPHATES.

Pfeffer [18] has suggested that insectivorous plants derive both nitrogen and phosphorus from their prey. The following laboratory experiments were carried out to determine the absorption of orthophosphates from the pitcher cavity in *Sarracenia purpurea*. The plants formed part of the group secured at Whitings, New Jersey, for the laboratory experiments on absorption of nitrogenous compounds. The two series of experiments, on nitrogen compounds and phosphates, respectively, were made simultaneously but on different plants.

Technic.—The insect remains were removed from the pitchers as in the experiments on absorption of nitrogenous compounds. Then 10.00 c.c. of the phosphate solution were introduced with a pipette into each *empty* pitcher, the mouth of which was immediately closed with a tightly fitting cotton plug. The phosphate solution was exactly neutral in reaction, *i.e.*, had a hydrogen ion concentration of 10^{-7} or pH 7.0. It was prepared as directed by Levy, Rowntree, and Marriott,[23] whose procedure is based on that of Sörensen;[24, 25] 37 c.c. of a fifteenth molar solution of monopotassium dihydrogen orthophosphate and 63 c.c. of a fifteenth molar solution of disodium monohydrogen orthophosphate were mixed. The phosphate content of the resulting solution was determined by titration.

After this neutral phosphate solution had been in a pitcher for a definite period of time, varying between 7 and 20 days, the cotton plug was removed—it was always dry and not soiled by the pitcher contents; the liquid in the pitcher was drawn up into a serological pipette; its volume was recorded; and it was transferred to a beaker. The pitcher cavity was washed with several successive portions of distilled water; these were transferred in turn by means of the pipette to the beaker; and the phosphate content of the combined liquid and washings was determined by titration.



Plant of *Sarracenia purpurea* in full bloom, with open pitchers. Photographed in Ocean County, New Jersey, where vigorous pitchers attain a length of 10 or more inches.

All titrations of phosphate content were made with a standard solution of uranyl nitrate after the addition of acetic acid and sodium acetate; tincture of cochineal was used as an internal

indicator. The solution of uranyl nitrate was standardized against a definite weight of monopotassium dihydrogen phosphate as suggested by Giles.[26] Results were calculated as grams of phosphoric oxide, P_2O_5.

The difference between the weight of phosphoric oxide introduced into the pitcher and the weight of phosphoric oxide recovered in the fluid and washings from the pitcher represented the weight of that compound absorbed from the cavity by the pitcher.

Results of these experiments are given in Table V, and lead to the following conclusions. Absorption of phosphates occurred in all the pitchers. The individual pitchers do not show any

TABLE V.

Absorption of Phosphates from the Pitchers of Sarracenia purpurea.

Number of pitchers.	Period of absorption, days.	Weight, in grams, of phosphoric anhydride.			Per cent. of introduced phosphoric anhydride absorbed.		Volume changes.			
		Introduced.	Recovered.	Absorbed.			Volume of phosphate solution introduced.	Volume of solution recovered.	Decrease in volume.	Decrease in volume calculated as per cent. of volume introduced.
							c.c.	c.c.	c.c.	
1	7	0.04681	0.03515	0.01166	24.91	Average 21.68	10.00	3.50	6.50	65.00
1	7	0.04681	0.03818	0.00863	18.44					
1	12	0.04681	0.03636	0.01045	22.33	Average 22.98	10.00	6.00	4.00	40.00
1	12	0.04681	0.03575	0.01106	23.63		10.00	5.90	4.10	41.00
1	20	0.04681	0.03303	0.01378	29.44	Average 26.86	10.00	5.45	4.55	45.50
1	20	0.04681	0.03545	0.01136	24.27		10.00	5.85	4.15	41.50

definite relation between the period of absorption and the per cent. of the introduced phosphoric oxide absorbed. When the two experiments of each period are averaged, and the averages are compared, the absorption appears to have been progressive throughout the entire 20 days, but to have been most rapid during the first 7 days. In a given time, the pitcher contents usually showed a greater percentage decrease in volume than in phosphoric oxide content; this indicates that water was absorbed more rapidly than phosphates from the solution in the pitcher cavity.

ABSORPTION OF THE LITHIUM ION.

These experiments were also made on plants of *Sarracenia purpurea* in the laboratory. A double normal solution of neutral lithium citrate ($Li_3C_6H_5O_7$) was prepared from lithium car-

bonate and citric acid. The solution was filtered; and 20 c.c. of the filtrate were introduced into each of four open pitchers, which were then closed with tightly fitting cotton plugs. One pitcher was examined at the end of seven days, the other three pitchers at the end of fourteen days. Each pitcher was cut from the plant at its base; and its exterior was well washed with a stream of distilled water from a wash bottle. The cotton plug was removed; the bottom portion of the pitcher was cut off just above the beginning of the pitcher cavity; the contents were permitted to run out; all insect remains were removed with a platinum needle; and the entire interior of the pitcher was repeatedly flushed, and its lid and exterior washed with distilled water until the wash water no longer imparted the lithium color to the non-luminous Bunsen flame.

The pitcher was next dried at 100° C., then ashed, in a platinum crucible. The ash was treated with 0.5 c.c. of concentrated hydrochloric acid and 2.0 c.c. of distilled water; and the resulting solution was filtered through a small, moistened, ashless filter-paper.

Lithium was identified in this solution of the ash by the crimson color imparted to the non-luminous Bunsen flame, and by spectroscopic examination of this colored flame by means of a Hofmann direct vision spectroscope with a scale previously calibrated for the lithium and sodium lines. The ash from all four pitchers yielded the same result.

As a control, examination was made of a composite sample of dried tissue obtained from fifty-nine open pitchers of *Sarracenia purpurea* which had been thoroughly cleansed from insect remains. These pitchers were obtained at the same time and place (Whitings) as the plants used in the tests on absorption of lithium. The dried tissue was ground so that it passed completely through a sieve with 20 meshes to the linear inch. A five-gram sample of the ground tissue was ashed in platinum. A loop of platinum wire was dipped into concentrated hydrochloric acid, then into the ash, and finally was placed in the non-luminous Bunsen flame. Neither the flame reaction (color) nor the spectral line of lithium appeared.

These results show that lithium is not a normal constituent of the tissues of *Sarracenia purpurea*, and that the pitchers of

this plant absorb the lithium ion from its neutral solution when such a solution is introduced into the pitcher cavity.

The spectroscopic examinations were made, in collaboration with Dr. Charles B. Bazzoni, in the Randal Morgan Laboratory of Physics of this University.

RESPONSE OF THE PITCHERS TO STIMULATION.

In 1875 Mrs. R. M. L. Austin, a California botanist, discovered that the introduction of meat into the pitcher cavity causes the pouring out of an additional supply of pitcher liquor in *Darlingtonia californica.* The following quotation is from a letter written by Mrs. Austin to Mary E. Pulsifer Ames, and was published by the latter:[19] "In July, 1875, I fed a great many of the leaves, some with fresh raw mutton and others with that which was boiled. The liquid, in the course of a week, would fill the tubes and flow out of the orifice." According to Asa Gray,[20] Mrs. Austin, studying *Darlingtonia californica,* found that "the watery liquid in the pitcher, which must be wholly a secretion, is much increased in quantity after the capture of insects."

In certain of our experiments in the field, a definite volume of a solution was introduced into pitchers which were then closed in the manner described in the sections on absorption. After the lapse of a definite period of time, from one to ten days, the average volume of the pitcher contents was determined in the usual way. From this average volume was subtracted the sum of the volume of solution introduced plus the average volume of the pitcher liquor in pitchers of the same species and same type (closed, open, or plugged); the remainder was the average increase in volume of the liquid pitcher contents, due to outpouring of additional liquor as the result of stimulation of the pitchers by the introduced solution. This average increase in volume was then calculated as per cent. of the average volume of the pitcher liquor of such pitchers.

Fresh skim milk was diluted with an equal volume of water, sterilized by heat, cooled to atmospheric temperature, and used in stimulation tests. The *average increase amounted to as much as* 1200 per cent. in 6 days in closed pitchers of *Darlingtonia californica,* 1000 per cent. in 4 days in closed pitchers of *Sarracenia flava,* and 900 per cent. and 500 per cent., respectively, in

5 days in plugged pitchers of *S. Sledgei* and *S. Drummondii*. With a given species and pitchers of a given type, the increase became more marked, the longer the time elapsed between introduction of the diluted milk and withdrawal of the pitcher contents, and the greater the volume of milk introduced.

Beef broth produced an *increase* of over 300 per cent. in pitchers of all three types in *Darlingtonia californica* in 5 days. It also produced increases of over 1700 per cent. and 600 per cent., respectively, in closed and open pitchers of *Sarracenia flava* in 4 days; the increase in one closed pitcher was over 2400 per cent.

Increases in the volume of the pitcher secretion were produced by certain reagents: dilute solution of potassium ferrocyanide, dilute solution of potassium ferricyanide, 2 per cent. solution of ferrous sulphate. The ferrous solution was introduced into pitchers of *Sarracenia Sledgei, S. flava,* and *S. Drummondii,* the other solutions into pitchers of *S. flava* only. A 2 per cent. solution of ferric ammonium sulphate, to which sodium acetate had been added, killed the pitchers of all three species within a few days after its introduction.

When introduced into the pitchers, raw egg-white produced no change in the volume of the pitcher liquor. This was also true of certain solids: coagulated egg-white, fibrin, casein, and cheese.

In the experiments on *Darlingtonia californica,* cubes of lean beef were introduced into the pitchers by means of forceps, and fell to the level of the pitcher liquor. Each edge of a cube was one-eighth inch long. When raw beef was used, an increase in volume of the pitcher liquor occurred in pitchers of all three types —closed, open, and plugged—but was always less than 200 per cent. in 7 days. When cooked beef was used, little, if any, increase took place in the volume of the liquor in either open or plugged pitchers.

This phenomenon of secretion of an abnormal volume of pitcher liquor is not in conflict with that of absorption. The decrease in volume of the pitcher contents, as a rule, occurred less rapidly than the absorption of nitrogenous compounds, and more rapidly than the absorption of phosphates from their respective solutions. Moreover, in the absorption experiments in which a buffer was added to the solutions of the nitrogenous compounds,

those compounds were absorbed while the pitcher contents increased in volume. An increase in volume of the pitcher contents also occurred in the experiments on the absorption of the lithium ion. In the plant economy, this increased secretion probably represents a result of natural selection, in which there has gradually developed a rise in the level of the pitcher liquor that insures the covering of captured insects which otherwise would lie in a dry and undigested state above the normal level of that fluid.

RESPONSE OF THE PITCHERS TO INTRODUCED ACID AND ALKALI.

Dilute aqueous solutions of acids (hydrochloric and acetic) and of sodium hydroxide were also introduced into the pitchers of certain species, and the pitcher contents examined 5 days later.

The pitcher liquor in open pitchers of *Darlingtonia californica*, *Sarracenia Sledgei*, and *S. Drummondii* and in plugged pitchers of *D. californica* is neutral to litmus, that in closed pitchers of *S. flava* acid, and that in open pitchers of *S. flava* faintly acid to neutral to litmus. The solutions introduced into the pitchers were tested, and possessed either a distinctly acid reaction (hydrochloric acid, acetic acid) or a distinctly alkaline reaction (sodium hydroxide) to litmus. Each pitcher received a definite volume (from 3 to 30c.c., usually 5c.c.) of a solution of *one* of the reagents.

The acetic acid was used as a 0.05 per cent. solution with the species of *Sarracenia* just mentioned, and as a 0.10 per cent. solution with *Darlingtonia californica*. Within 5 days, the reaction of the pitcher contents to litmus had become neutral in the plugged pitchers of *Darlingtonia californica*, in the open pitchers of that species, *Sarracenia Sledgei*, and *S. Drummondii*, and in the closed pitchers of *S. flava*, and was acid in the open pitchers of the last-named species. The volume of the pitcher contents showed a marked decrease in all the *Sarracenia* pitchers, and a slight increase in those of *D. californica*.

The hydrochloric acid was usually used as a 0.05 per cent. solution. Within 5 days, the pitcher contents had become neutral to litmus in open pitchers of *Darlingtonia californica*, and *Sarracenia Drummondii*, and in the majority of those of *S. Sledgei*; they were faintly acid to litmus in both open and closed pitchers of *S. flava*. The *Sarracenia* pitchers showed a decrease in the volume of their contents. A 0.2 per cent. solution of hydrochloric

acid was also introduced into both open and plugged pitchers of *D. californica;* some pitchers were injured, becoming partly shriveled and brown; their contents were faintly acid to litmus; other pitchers were unharmed, their contents were neutral to litmus at the end of the 5 days.

Sodium hydroxide was used as a 0.02 per cent. solution in both open and plugged pitchers of *Darlingtonia californica,* and as a 0.05 per cent. solution in open pitchers of *Sarracenia Sledgei* and *S. Drummondii* and in both open and closed pitchers of *S. flava.* Within 5 days, the contents of the pitchers had become neutral to litmus in all the experiments. The pitcher contents decreased in volume in the *Sarracenia* pitchers and increased slightly in volume in those of *Darlingtonia californica.*

It is of interest to note that, in the experiments with acids, an acid reaction was retained only in the pitchers of *Sarracenia flava;* the pitcher liquor of this species normally tends to have an acid reaction, and its protease acts best in an acid medium.

After the introduction of either dilute acid or dilute alkali into the pitchers, the normal reaction of the pitcher contents was restored, as a rule, in a few days. This return of the pitcher contents to their normal reaction recalls the behavior of the human stomach under somewhat similar conditions, as studied by Spencer, Meyer, Rehfuss, and Hawk.[27]

SUMMARY.

I. A résumé has been given of our observations on:

1. The occurrence of reducing sugar in the nectar.

2. The wetting action of the pitcher liquor on insects.

3. The occurrence of a proteolytic enzyme in the pitcher liquor of the Sarracenias and its absence from that of *Darlingtonia californica.*

4. The freedom from bacteria of the pitcher cavity and liquor in closed pitchers.

5. The occurrence of proteolytic bacteria in the contents of open pitchers, in which captured insects were present.

6. The secretion of additional pitcher liquor in response to stimulation by certain foods such as milk and meat broth, and by certain other substances.

7. The response by the pitchers to introduction of acid or alkali in dilute solution.

II. A detailed account has been given of our studies on absorption by the pitchers of substances introduced into their cavities. These studies led to the following general conclusions:

1. Water, which was introduced into the pitchers of *Darlingtonia californica* and the Sarracenias, underwent absorption.

2. When an aqueous solution of a nitrogenous compound was introduced into pitchers of the Sarracenias, both the nitrogenous compound and the water were absorbed, but at a different rate; absorption of the nitrogenous compound was usually more rapid than that of the water.

3. When a phosphate buffer was added to the aqueous solution of the nitrogenous compound, the latter was absorbed while the pitcher contents increased in volume.

4. When a neutral phosphate solution was introduced into pitchers of *Sarracenia purpurea,* both the phosphate and the water were absorbed, but at a different rate; absorption of the phosphate was less rapid than that of the water.

5. The per cent. of the introduced nitrogenous compound or phosphate absorbed usually increased with the period of absorption.

6. When a solution of neutral lithium citrate was introduced into pitchers of *Sarracenia purpurea,* the lithium ion was absorbed.

7. Absorption by the pitchers of substances introduced into their cavities in solution has been demonstrated (*a*) by the decrease in the nitrogen or phosphate content of the solution, and (*b*) by appearance in the pitcher tissues of lithium, an element not normally present.

8. These results indicate that the proteolytic products, formed in the pitcher cavity by digestion of the prey, are absorbed by the pitchers and are utilized for the nutrition of the plant. They also indicate that phosphates, and probably other mineral foods, derived from the prey, are absorbed and utilized in like manner.

The authors are deeply indebted to Dr. John M. Macfarlane, director of the botanic laboratory and garden of this University, who has placed all the facilities of his department at their disposal, and has offered many suggestions of great value to them. They also acknowledge with pleasure the hearty coöperation of the staff of the Randal Morgan Laboratory of Physics of this

University. The radiographs of pitchers containing captured insects are the work of Dr. Arthur W. Goodspeed; Dr. Horace C. Richards collaborated in the fluoroscopic examination of such pitchers, and Dr. Charles B. Bazzoni in the spectroscopic examination of the ash.

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(Citations numbered 1 to 20 inclusive refer to insectivorous plants. The remainder of the papers cited deal with methods of research.)

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Method of Cleaning Coil Springs. DONALD A. HAMPSON. (*Machinery*, vol. xxvi, No. 4, p. 343, December, 1919.)—A certain manufacturer who produces coil springs from copper-finished steel wire had considerable trouble in keeping them bright and free from oil. These springs are two inches long and have an extension at each end that projects at right angles to the axis of the spring. In the production of these springs, the use of lubricant is imperative in the operation of the forming machine, which results in the presence of oil on the finished product. Unless this oil is removed, the bright copper finish of the wire becomes dull, and thus the selling qualities are lessened. This objection is now overcome by the method to be described.

The springs are packed in a wooden box having a removable cover. A one-inch shaft passes through the box and is secured to its sides by flanged collars. The shaft is supported by a bearing on each side of the box, and carries a driving pulley on one end by means of which the box is revolved at the rate of forty revolutions per minute. After the box has been filled with springs, a quantity of sawdust is dumped in and the cover fastened on. By revolving the box for about twenty minutes, the sawdust is circulated through the springs, during which process the oil is completely absorbed and the springs are given a uniform polish. The springs tend to become tangled if the box is revolved longer than the time stated, or if the box is only partly filled.

R.

Test of Alpine Tanks.—The tank in peace-time is to be applied to transporting passengers and goods to hotels on mountains where carriage roads are lacking. A test of this method of mountain climbing was held September, 1919, in the Department of France in which Mt. Blanc is situated. The course was 4.7 km. long with an ascent of .7 km. over mule tracks, peaty ground, and meadow land, through fords and along deep ravines. The Renault caterpillar tractor made the ascent in 83 minutes, the descent in 66 minutes, and completed three trips in a day.

G. F. S.

THE RELATIVE MERITS OF MONOCULAR AND BINOCULAR FIELD-GLASSES.*

THE RESULTS OF AN INVESTIGATION UNDERTAKEN BY THE SUB-COMMITTEE OF THE NATIONAL RESEARCH COUNCIL ON "MONOCULAR *versus* BINOCULAR FIELD-GLASSES."

BY

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THE investigation of the relative merits of monocular and binocular field-glasses was undertaken by members of the staff of Nela Research Laboratory upon request from the National Research Council. In the first instance the Laboratory was asked for a critique of the literature on the subject, but since this failed to establish definitely any decisive advantages for the binocular, it was deemed wise to institute an extensive investigation of the problem.

To this end a comprehensive program of procedure was formulated, as outlined in the Introduction, but owing to the urgent demand for the completion of the investigation it was necessary to omit certain parts of the program and to depend upon the findings of the practical field test which, according to the plan of work, should constitute the final stage of the investigation. Unfortunately, therefore, the research is not complete, but the results of the field test are sufficiently indicative to justify certain tentative conclusions.

Except for the Introduction, which covers briefly the survey of the literature of the subject, as given in the critique referred to above, and which also includes an outline of the program of work as formulated at the beginning of the investigation, the

* Communicated by Edward P. Hyde.

[1] The Committee is indebted to Messrs. Cobb and Weniger for practically all of the experimental work.

text of the present paper is quite closely a verbatim copy of the report transmitted to the National Research Council.

INTRODUCTION.

The general problem of the relative merits of monocular and binocular field-glasses is many-sided; comparisons may be made on the basis of mechanical and optical design and construction, on questions of pure physiologic optics, and on the use and manipulation of the glasses under service conditions.

A comparison of the two types of glasses as to their mechanical properties yields the following: The limits of toleration for departure from parallelism of the optic axes of the two telescopes of a binocular are very small. Consequently, the instrument may be rather easily thrown out of alignment by falls and blows, and as a result cause an undue amount of eye fatigue. The binocular requires three adjustments (separate focus for each eye, and adjustment of interpupillary distance) to fit it to the eyes of a particular observer, and in the type adopted by the army (without means of focussing both telescopes simultaneously) the focus cannot be conveniently changed while the instrument is in use; the same hand that holds the monocular can also focus it at any time. The binocular of the type adopted by the army (prism adjustment and not objective adjustment) cannot be cleaned thoroughly in the field on account of resultant lack of parallelism of the axes upon reassembling; there is no such trouble with the monocular. The binocular is bulkier and heavier and requires a leather carrying case with a shoulder strap, which is always in the way; the monocular can be carried in a shirt pocket and is instantly ready for use. The speed of production of the binocular is slower, and its cost is about three times that of the monocular.

The questions of physiologic optics that enter into this comparison are of two kinds:

(1) Those concerning the stereoscopic effect, and

(2) Those concerning any possible increase in visual sensitivity apart from the stereoscopic effect.

With regard to the stereoscopic effect, it is to be remarked that the factor which governs the absolute perception of depth is the parallax, *i.e.*, the difference between the two angles sub-

tended at the two eyes respectively by the images of two points of different remoteness in the field. The parallax, so measured, and hence the sensitivity to depth, is obviously increased directly as the magnification, and is also increased directly as the distance between the objectives of the binocular.

Magnification has the effect of proportionately decreasing the apparent depth of objects relatively to their transverse dimensions; while increasing the distance between the objectives apparently decreases both size and distance without distortion.[2] Neither of these appearances is to be taken as an index to depth-sensitivity, which depends solely upon the considerations mentioned in the preceding paragraph.

The distance between the objectives of prism binoculars as ordinarily constructed is approximately 1.75 times the normal interpupillary distance. Taking 65 mm. as the normal interpupillary distance, and 30 seconds as an average value of the parallax angle that can be detected by an observer, a simple computation shows that with a binocular magnifying six diameters, a point at a distance of 4670 metres from the observer can just be distinguished as being nearer than an infinitely distant background. For a glass magnifying eight diameters, this distance is 6250 metres. In other words, for viewing objects at distances greater than the above, the binocular offers no advantage over the monocular from the standpoint of stereoscopic effect.

It seems obvious that an appearance of relief would reveal to binocular vision an object monocularly indistinguishable from its more remote and variegated background. The influence of this factor on visual sensitivity to detail seems to have escaped experimental attack, although it is quite apparent in the use of the simple stereoscope.

With reference to visual sensitivity apart from steroscopic effect, it seems to be established that binocular observation for the ordinary individual gives a greater sensitivity to brightness and to differences of brightness than monocular observation yields; and this holds true for both dark-adapted and light-adapted eyes. It has been asserted also that visual acuity, or sensitivity to detail, is higher for binocular vision than for monocular, but we have been unable to locate any reports of quantitative experiments. It

[2] Pulfrich, *Zeit. f. Instk.*, **25**, 1905, p. 233.

also appears in the work of Dawson [3] that the time required for making a difficult photometric judgment is considerably shorter, and the percentage of accuracy greater, for binocular observation than for monocular.

Data on questions attending the use of the glasses in practice, such as the time required for "picking up" a distant object, the time required for distinguishing the detail on it, etc., do not seem to be on record. This survey of the field shows clearly that the experimental work of the committee lies for the most part along two lines:

(1) Investigations of some of the problems in physiologic optics under out-of-door conditions, using field-glasses, the results of which may in some cases merely substantiate conclusions reached by pure laboratory study without glasses, and

(2) A statistical study of the results obtained with the two types of glasses when used by men who were training for work requiring the use of glasses in warfare.

An additional question that is certainly worthy of study, and is applicable to both monoculars and binoculars, is that of distinguishing colored objects from their surroundings by the use of suitable colored screens, when such objects are indistinguishable in ordinary light. The use of colored screens should aid vision also by the exclusion of scattered light and by the reduction of the effect of chromatic aberration in the eye.

Plans were therefore made to ascertain the relative merits of the two types of glasses by an experimental study of the following problems:

(1) Non-stereoscopic acuity tests under daylight illumination,

(2) Non-stereoscopic acuity tests under twilight illumination,

(3) Effect of parallax on the discrimination of detail,

(4) Discrimination of objects possessing a brightness difference and the effect of parallax on this discrimination, and

(5) Effect of colored screens in the eye-piece on the discrimination of detail and brightness differences.

Unfortunately, work on the last three of these was stopped by an urgent request to conduct the statistical study with military officers as observers. The latter was carried on at Camp Meade, Maryland, under the immediate supervision of the Board to Test Snipers' Equipment, Colonel Wm. P. Jackson, Chairman.

[3] *Brit. Jour. Psych.*, 6, 1913, p. 78.

PART I.

NON-STEREOSCOPIC ACUITY TESTS UNDER DAYLIGHT ILLUMINATION.

THE first question to which an answer was sought in this comparative study of monocular and binocular vision was whether the two eyes, acting in harmony, have appreciably greater sensitiveness than either one alone; to make it concrete, whether both together can distinguish small details with greater speed and accuracy than either one alone when those details are presented on a flat field at such a distance that vision must be aided by the use of a field-glass.

CONDITIONS, APPARATUS AND PROCEDURE.

The work was conducted under the open sky upon the grounds of the Mayfield Country Club, near Cleveland. The weather, during the course of the experiments which enter into the results, was variable—sometimes clear, sometimes slightly hazy, sometimes cloudy and usually breezy. At times the wind was such as to make it difficult to maintain the position of the glass before the eyes with a sufficient degree of steadiness.

The land lay so that between the observer and the object there were three depressions. The four eminences on this range—the position of the observer being one—were of such height that the line of vision passed over them at about the height of an ordinary individual's eyes. From the last of these the land sloped gently downward toward the test object, so as to cut off the observer's view of all objects at that point less than about 130 cm. from the ground.

To conduct the work it was necessary to communicate rapidly between the two ends of the range, something over half a mile. This was made possible by a system of visible signals and the use, at either end of the line, of a terrestrial telescope having a magnifying power of sixty diameters. The atmospheric impediments, although absolutely less effective, were naturally most obvious through these telescopes, more so than with the unaided eyes or with a field-glass of comparatively low magnification. A marked heat-shimmer was thus often observed over the range, almost always when the sun was shining. On such days as the sky was

partially clouded there would be periods of sunlight and shade over the range, and often a nearly maximal heat-shimmer would be observed to appear almost immediately following the appearance of the sunlight, to disappear again as quickly as a cloud shaded the range.

The appearance of the test object can be best described by saying that it was a white square on a black ground with a central strip, in area one-third of the square, removed, thus leaving two white bars (see Fig. 1). Taking the width of one bar as unity, the space between them is 1, and their length is 3. By a specially devised mechanical arrangement this figure could be changed proportionately in all its dimensions, the width of the bars and the intervening space decreasing by indefinite gradations from 12 cm. to 0 with a simultaneous and proportional decrease in the length of the bars from 36 cm. to 0. The case enclosing the mechanism, a shallow box, 90 cm. square, could be rotated about a central axis normal to its face so as to present the bars inclined at any angle.

The sizes of the test object are designated by numbers, and the consecutive sizes differ in the ratio of $1 : \sqrt[8]{\frac{1}{2}}$. The largest is designated *0*, where the width of the white bars is 12 cm. Therefore, if n be the numeral designating the size, the width of each bar will be $12(\frac{1}{2})^{n/8}$ cm. The sizes for the various designations are given in Table I, along with the angles subtended (without magnification) at the observer's station.

TABLE I.

Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.
0	12.00	0.431	8	6.00	0.216	16	3.00	0.108
1	11.00	.395	9	5.50	.198	17	2.75	.099
2	10.09	.363	10	5.05	.182	18	2.52	.091
3	9.25	.333	11	4.63	.166	19	2.31	.083
4	8.49	.305	12	4.24	.152	20	2.12	.076
5	7.78	.280	13	3.89	.140	21	1.95	.070
6	7.14	.257	14	3.57	.125	22	1.78	.064
7	6.54	.235	15	3.27	.118	23	1.64	.059
8	6.00	.216	16	3.00	.108	24	1.50	.054

In the experiments the test object was shown to the observer in only two positions, with the bars either horizontal or vertical. He was required, at a word, to look at the object with the glass and announce the position in which he saw the bars to be.

The stimuli comprising a series of experiments, as finally settled upon, were ten to twelve consecutive sizes of the object, presented each once in the vertical and once in the horizontal position. These were presented in shuffled order determined in advance and written on duplicate protocol sheets. One of these was in the hands of the recorder, whose place was at the side of the observer, and the other was used by the operator of the test object at the other end of the range.

The order of procedure was as follows. The operator set the

FIG 1.

Operator's station.

test object to the size and position of the first stimulus of the series, according to his sheet, and signalled "ready." The recorder, receiving the signal, gave the word "go" to the observer and started a stop-watch as the latter raised the glass to his eyes. The observer announced to the recorder the instant he distinguished the position of the test object by the word "up" for the vertical, "down" for the horizontal position. In the third case, as soon as he was satisfied that he could not distinguish the position of the object he spoke the word "cross." By means of a semaphore (Fig. 2), he signalled the same answer to the

operator at the other end of the range. The recorder wrote the answer and the time of observation on his sheet, and the operator wrote the answer signalled and at once set the object for the next stimulus and gave the "ready" signal. The observer, upon receiving the signal by way of the recorder, acknowledged it by throwing the semaphore arm into a meaningless position and again awaited the word "go." Several check signals were ex-

FIG 2.

Observer's station.

changed in the course of the series to make sure of agreement on the order. The recorder's sheet was the one preserved, after being checked with the other.

For investigating one eye alone, a cap with a ground-glass bottom was slipped over the opposite objective of the field-glass. With each observer three series were always run in immediate succession—right eye alone, left alone, and both eyes—the order of these three being systematically varied in all possible permutations. The three observers assumed the duties of recorder and operator in rotation with as few departures from regularity as were consistent with practical convenience. The work was done from August 30 to September 25, 1917, and between the hours

9.00 A.M. and 5.30 P.M. The observer was always standing with no additional support for any part of his body, nor for the glass. The test object was 956 metres distant from him in a direction south 40° east. Before and between series he focussed the glass, and also *ad libitum* during observation.

The instrument used was a Leitz prism binocular having a magnifying power of six diameters and ⅞-inch objectives. This instrument was chosen from among those at hand (including a five- and a ten-power navy binocular), largely because it was provided with a simultaneous focussing adjustment, which the others lacked, as well as with a separate adjustment for one eye. Its magnification also seemed best suited for experimentation at the available distance.

Upwards of 4000 experiments were made. The earlier portion of these was considered to be vitiated by the lack of special experience, so that about 3600 have been taken into account in computing the results following.

RESULTS.

The results, including all of the data from the latter group of experiments, are given in Tables II, III, and IV. It is to be noticed that under those conditions in which both right (R) and indeterminate (X) answers were given, the average time for the indeterminate answer is almost always longer than the average time required for the right answer. This simply means that the observer did not prematurely give up the attempt to appreciate the direction of the stripes on the test object. On the average, he devoted more time to the observation than was necessary to see the test object correctly in the favorable cases.

At worst, the object appeared as a small white blur, of variable size. In some cases it would have a fluctuating appearance, the direction appearing at one instant vertical, at another horizontal. This might continue until the observer gave up the attempt to name the direction. Or possibly, after a period of indistinctness or fluctuation, the bars would flash into consciousness in a vivid way that was unmistakable. Often, on the other hand, after prolonged observation, the answer was rendered with misgivings and proved to be correct. Usually, if the object was of such size as to be at or near the limit of visibility, the observer would feel himself impelled to continue his efforts. When the

object was much below the critical region he apparently recognized the fact and gave up his efforts to see it earlier than in the corresponding cases with a larger stimulus. This fact appears from the tables in examining the times under the heading *X*.

In a very few cases the observer returned an answer which was positively wrong. *A priori* this would suggest that he had guessed at the position of the object and missed it. On this supposition it would have to be further considered that he had also guessed right, probably with equal frequency and that hence his number of truly right answers—that is, the number in which he could be supposed to have actually seen the object—would be the recorded number less the number of wrong answers. However, the scarcity of wrong answers, the (often) long time taken in rendering them, and the fact that in the case of observer G. H. (who returned the largest number) they occurred under conditions within which no doubtful judgments whatever were given, made it appear that the wrong answers were not due to careless observation, nor to guessing, but rather to the supervention of some unusual condition in the observer. It was, therefore, decided to leave them entirely out of consideration. As a matter of fact, the final results are only very slightly altered by so doing.

On examining the recorded times required for observation, it was noticed that of the experiments under any one condition a few showed inordinately long times, as though these also represented conditions much out of the usual run. To these groups (representing practically all the observations) Chauvenet's criterion was applied, and the experiments having improbable time values were also eliminated. The remaining data are given in Tables II-A, III-A, and IV-A.

The values in the last-mentioned tables were used in making the plots (Figs. 3, 4, and 5). Average times representing less than five results were not plotted. The especial points to be noticed in these are:

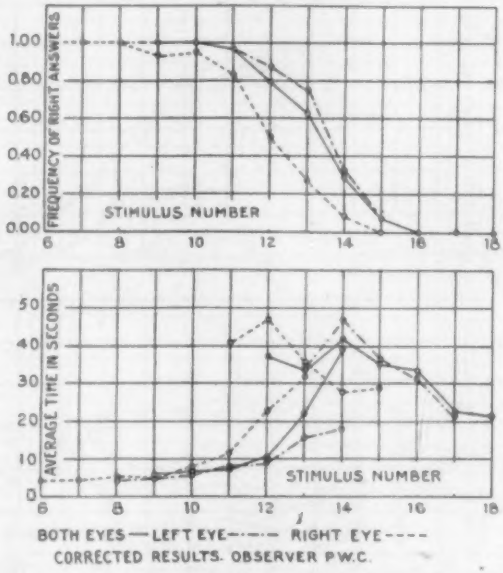
(1) With relatively large stimuli the time of observation is small, two to eleven seconds, increasing rather rapidly with decrease in stimulus size once the region is reached where the indeterminate judgments appear.

(2) With stimuli of such size that both right and indeterminate judgments appear, the time required is larger for the latter than for the former.

(3) The time of observation required for indeterminate judgments is longer in the stimulus-region of mixed judgments than it is with smaller stimuli where indeterminate judgments are the rule.

In the separate use of each eye alone all three of the observers showed distinctly better results with one eye than with the other. The fact that the better results were obtained with the right eye

FIG 3.



of one observer (W. W.) and with the left of the other two (P. W. C.) and (G. H.) would indicate that the difference was not due to imperfect matching or adjustment of the optical parts of the binocular.

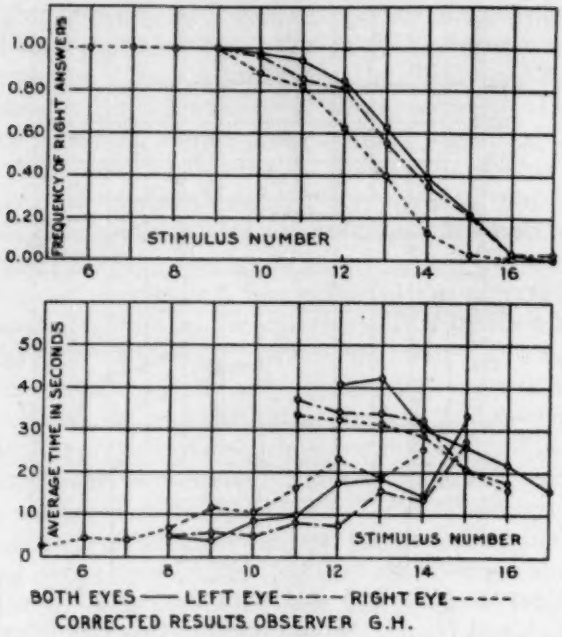
The final comparison to be made is between the results obtained with the better eye alone, and those obtained binocularly.

In the case of observer P. W. C., the results obtained with the left eye alone were distinctly better than those obtained with the two eyes together. It appears further that the difference between the two eyes is greater in the case of this observer than for either of the others, the binocular results falling in an intermediate position (Fig. 3). Measured as difference in the size of the test object the left eye is about 4 per cent. better than both, the right

11 per cent. poorer. These differences are computed from the segment of the abscissa line corresponding to 50 per cent. frequency cut off by the respective pairs of curves in the plot.

With this observer the times run a course parallel with the degree of uncertainty of judgment. At stimulus No. 12, to illustrate, the frequencies of right answers are 0.500 with the right eye, 0.794 with both, and 0.875 with the left. The corresponding

FIG 4.



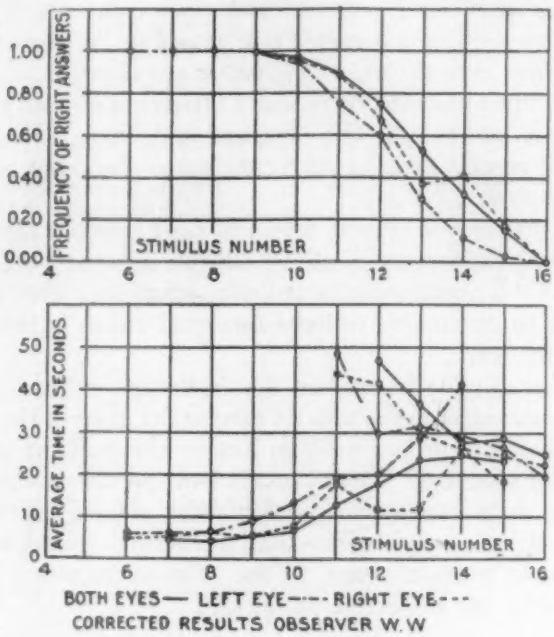
times are 22.6, 10.3, and 7.9 seconds, greater as vision is more uncertain and *vice versa*. It would seem that this observer had distributed his time fairly consistently with the difficulty of observation.

Turning to the plot of the results of observer G. H. (Fig. 4), we see that in his case the frequencies of right answers for binocular vision are greater than for either eye alone, the left and right eyes falling below to the extent of about 2 per cent. and 6 per cent. respectively. Referring to the time plot we see that the right eye falls off in frequency in spite of the greater time consumed in observation. On the contrary, with the left eye, as

compared with binocular vision the frequency is only slightly less, and the time of observation is also less, leaving open the possibility that the apparently better results with both eyes may be due to more careful observation rather than to binocular synergy.

The results of observer W. W. (Fig. 5) do not readily admit of estimations on which to base quantitative comparisons. His left eye shows about 7 per cent. poorer vision than both together.

FIG 5.



The frequencies for the right eye plot irregularly, and at stimuli Nos. 12 and 13 only does there appear to be a material advantage in favor of binocular vision. A glance at the time plot shows that here again the greater certainty of vision is accompanied by greater time of observation. In other words, the case is the same at these two points as it is in general for observer G. H.

The uncorrected data examined in the manner of the foregoing furnish no contradictory evidence. In general the differences just pointed out, both as to frequency and time, are less in amount, and the relations between them, therefore, less clear cut.

CONCLUSIONS.

The point investigated in this part of the work is whether in the use of a binocular field-glass the two eyes reinforce each other to any material extent. The conditions are full daylight illumination, and the criterion is vision of detail of minimal size and maximal contrast in a test object located entirely in one plane normal to the line of sight.

In the cases of two of the observers the eyes used singly show differences of about 4 per cent. and 7 per cent., respectively, in acuity. *No decisive advantage was found in the use of the two eyes together over the use of the better eye alone.*

In the third observer there was a difference in acuity of about 15 per cent. between the two eyes, and in his case *the use of both eyes gave results about 4 per cent. poorer than the use of the better eye alone.*

Such differences as were found to exist between the two eyes of the several observers would be difficult or impossible to detect by means of usual ophthalmologic practice. The observers could not be considered to have abnormal vision in the accepted sense of the term.

It is here to be remembered that in the two cases (monocular and binocular vision) the task of raising the glass to the eyes and maintaining it in proper position has, by the mode of procedure, been made identical. If this work had, on the contrary, been conducted with monocular and binocular glasses as supplied to the market, it seems obvious that the results would have been influenced to a great extent by the relative degrees of stability possible with the respective mountings.

EXPLANATION OF TABLES II–IV AND II-A–IV-A.

Tables II, III and IV are computed from all of the results in the experiments considered. *R* indicates "right answer," *W* "wrong" and *X* undetermined.

Under "Time" is given in each case the average time required for observation, followed by its mean deviation. Under "Number" will be found the number of experiments entering into the respective average time. The "frequency" applies to the stimulus-value, and is here the fraction of the whole number of experiments upon that stimulus in which right answers were given.

Tables II-A, III-A and IV-A were similarly prepared after eliminating those experiments in which wrong answers were given and those in which the time of observation was of improbable length (see page 194).

TABLE II.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer P. W. C.

Stimulus Number	Time in Seconds			Number			Frequency
	R	*W*	*X*	*R*	*W*	*X*	$R/(R+W+X)$
			Both eyes.				
9	7.1 ± 3.7	.....	.....	41	0	0	1.000
10	8.2 ± 4.2	.....	.....	41	0	0	1.000
11	12.3 ± 7.6	.....	82.0 ± 0	40	0	1	0.976
12	15.3 ± 8.8	31.0 ± 0	37.1 ± 14.4	33	1	7	0.805
13	27.0 ± 13.8	30.0 ± 19.0	38.9 ± 12.8	24	2	15	0.586
14	39.0 ± 16.2	46.0 ± 0	45.8 ± 18.1	11	1	29	0.268
15	31.3 ± 16.2	.....	37.5 ± 12.2	3	0	38	0.073
16	.....	.....	35.5 ± 10.3	0	0	38	0.000
17	.....	.....	25.1 ± 8.6	0	0	38	0.000
18	.....	.....	22.2 ± 7.5	0	0	38	0.000
			Left eye.				
8	5.1 ± 1.6	.....	.....	38	0	0	1.000
9	5.6 ± 1.8	.....	.....	41	0	0	1.000
10	7.4 ± 3.4	.....	.....	41	0	0	1.000
11	14.2 ± 10.4	.....	33.0 ± 0	40	0	1	0.976
12	14.8 ± 10.5	.....	33.8 ± 5.3	37	0	4	0.902
13	24.5 ± 15.2	35.0 ± 0	42.0 ± 12.4	30	1	10	0.732
14	28.3 ± 15.4	.....	46.7 ± 16.0	16	0	25	0.390
15	20.0 ± 2.7	.....	38.6 ± 13.0	3	0	38	0.073
16	.....	.....	33.2 ± 12.6	0	0	38	0.000
17	.....	.....	24.2 ± 7.3	0	0	38	0.000
			Right eye.				
6	4.8 ± 1.4	.....	.....	38	0	0	1.000
7	5.2 ± 2.1	.....	.....	38	0	0	1.000
8	6.3 ± 2.4	.....	.....	38	0	0	1.000
9	10.0 ± 7.5	.....	43.0 ± 17.0	39	0	2	0.951
10	12.0 ± 7.9	.....	29.0 ± 2.0	39	0	2	0.951
11	15.6 ± 8.8	.....	47.1 ± 12.4	34	0	7	0.829
12	22.6 ± 11.6	.....	50.0 ± 13.6	20	0	21	0.488
13	31.9 ± 13.1	77.0 ± 0	39.9 ± 10.5	10	1	30	0.244
14	31.3 ± 3.8	.....	31.0 ± 9.2	3	0	38	0.007
15	.....	.....	28.8 ± 8.4	0	0	41	0.000

TABLE II–A.

Corrected Results.

A Summary Similar to Table II, but with Wrong Answers Omitted and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer P. W. C.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	*R*/(*R*+*X*)
		Both eyes.			
9	5.6 ± 1.8	.....	37	0	1.000
10	6.1 ± 2.0	.....	36	0	1.000
11	7.0 ± 1.5	82.0 ± 0	29	1	0.967
12	10.3 ± 3.3	37.1 ± 14.4	27	7	0.794
13	22.0 ± 9.5	33.6 ± 8.1	21	13	0.617
14	39.0 ± 16.2	41.8 ± 14.3	11	27	0.289
15	31.3 ± 16.2	35.3 ± 10.5	3	36	0.077
16	.....	33.3 ± 8.8	0	36	0.000
17	.....	22.7 ± 6.5	0	34	0.000
18	.....	21.4 ± 6.8	0	37	0.000
		Left eye.			
8	4.4 ± 0.9	.....	33	0	1.000
9	4.8 ± 1.0	.....	37	0	1.000
10	5.7 ± 1.4	.....	36	0	1.000
11	7.5 ± 2.5	33.0 ± 0	31	1	0.969
12	7.9 ± 2.7	33.8 ± 5.3	28	4	0.875
13	15.6 ± 6.2	34.6 ± 6.2	24	8	0.750
14	18.2 ± 5.0	46.7 ± 16.0	12	25	0.324
15	20.0 ± 2.7	36.7 ± 11.0	3	37	0.075
16	.....	31.5 ± 11.0	0	37	0.000
17	.....	21.8 ± 5.6	0	34	0.000
		Right eye.			
6	4.0 ± 0.5	.....	31	0	1.000
7	4.1 ± 0.8	.....	33	0	1.000
8	5.0 ± 0.7	.....	33	0	1.000
9	4.8 ± 0.8	43.0 ± 17.0	27	2	0.931
10	7.8 ± 2.9	29.0 ± 2.0	33	2	0.943
11	11.4 ± 4.7	40.8 ± 8.2	29	6	0.829
12	22.6 ± 11.6	46.9 ± 11.2	20	20	0.500
13	31.9 ± 13.1	35.8 ± 6.7	10	27	0.270
14	31.3 ± 3.8	27.6 ± 3.8	3	34	0.081
15	.....	28.8 ± 8.4	0	41	0.000

TABLE III.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer G. H.

Stimulus Number	Time in seconds			Number			Frequency
	R	*W*	*X*	*R*	*W*	*X*	$R/(R+W+X)$
			Both eyes.				
8	4.7 ± 1.8	.....	.....	38	0	0	1.000
9	7.0 ± 4.5	23.0 ± 0	.....	40	1	0	0.976
10	10.2 ± 7.3	.....	53.0 ± 0	40	0	1	0.976
11	15.2 ± 11.6	23.5 ± 2.5	34.0 ± 6.0	37	2	2	0.902
12	19.1 ± 13.2	41.5 ± 22.5	40.7 ± 14.0	33	2	6	0.805
13	18.4 ± 10.0	32.0 ± 0	42.1 ± 11.0	25	1	15	0.610
14	18.9 ± 10.1	31.0 ± 13.0	33.0 ± 12.0	16	2	23	0.390
15	33.1 ± 16.6	.....	25.8 ± 8.4	9	0	32	0.219
16	12.0 ± 0	.....	23.8 ± 9.6	1	0	37	0.026
17	.....	.....	19.2 ± 8.3	0	0	36	0.000
			Left eye.				
8	7.1 ± 4.9	11.0 ± 0	.....	37	1	0	0.974
9	6.7 ± 4.0	22.0 ± 0	.....	40	1	0	0.976
10	10.4 ± 7.3	.....	42.0 ± 0	40	0	1	0.976
11	12.3 ± 8.3	.....	37.2 ± 7.0	36	0	5	0.878
12	13.1 ± 8.9	9.0 ± 0	34.3 ± 8.7	34	1	6	0.830
13	20.0 ± 14.1	38.0 ± 0	34.0 ± 10.0	23	1	17	0.561
14	22.7 ± 16.4	17.5 ± 3.5	34.6 ± 15.5	15	2	24	0.366
15	27.3 ± 11.0	42.5 ± 9.5	28.3 ± 13.0	7	2	32	0.171
16	9.0 ± 0	120.0 ± 0	20.5 ± 9.1	1	1	37	0.026
17	14.0 ± 0	.....	17.7 ± 7.3	1	0	36	0.027
			Right eye.				
5	4.9 ± 3.1	.....	.....	38	0	0	1.000
6	4.4 ± 1.7	.....	.....	38	0	0	1.000
7	5.6 ± 3.0	8.0 ± 3.0	.....	39	2	0	0.951
8	8.1 ± 5.3	4.0 ± 0	.....	40	1	0	0.976
9	11.4 ± 7.1	13.0 ± 2.0	.....	39	2	0	0.951
10	14.5 ± 10.7	.....	46.5 ± 9.8	37	0	4	0.902
11	18.0 ± 12.5	.....	39.8 ± 14.8	33	0	8	0.805
12	23.0 ± 14.9	11.0 ± 0	32.2 ± 18.7	25	1	15	0.610
13	18.8 ± 8.9	35.0 ± 0	31.1 ± 10.4	16	1	24	0.390
14	25.2 ± 8.6	24.5 ± 19.5	28.7 ± 12.9	5	2	34	0.122
15	17.0 ± 0	17.0 ± 0	23.4 ± 8.7	1	1	36	0.026
16	.....	.....	18.7 ± 7.3	0	0	38	0.000

TABLE III-A.

Corrected Results.

A Summary Similar to Table III but with Wrong Answers Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer G. H.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	*R*/*R*(+*X*)
		Both eyes.			
8	4.7 ± 1.8	.....	38	0	1.000
9	4.0 ± 0.9	.....	30	0	1.000
10	8.3 ± 5.2	53.0 ± 0	38	1	0.974
11	9.6 ± 5.0	34.0 ± 6.0	33	2	0.943
12	17.1 ± 11.2	40.7 ± 14.0	32	6	0.842
13	18.4 ± 10.0	42.1 ± 11.0	25	15	0.625
14	14.6 ± 6.1	30.5 ± 9.4	14	22	0.389
15	33.1 ± 16.6	25.8 ± 8.4	9	32	0.220
16	12.0 ± 0	21.8 ± 7.7	1	35	0.028
17	.....	15.5 ± 4.8	0	31	0.000
		Left eye.			
8	4.9 ± 2.2	.....	33	0	1.000
9	5.3 ± 2.3	.....	37	0	1.000
10	4.9 ± 1.2	42.0 ± 0	26	1	0.963
11	7.9 ± 3.8	37.2 ± 7.0	29	5	0.853
12	7.4 ± 2.4	34.3 ± 8.7	26	6	0.812
13	15.4 ± 9.4	34.0 ± 10.0	21	17	0.553
14	13.6 ± 8.6	32.2 ± 12.8	12	23	0.343
15	27.3 ± 11.0	20.7 ± 5.8	7	26	0.212
16	9.0 ± 0	17.3 ± 6.0	1	34	0.029
17	14.0 ± 0	13.8 ± 3.9	1	30	0.032
		Right eye			
5	2.9 ± 0.6	.....	29	0	1.000
6	4.4 ± 1.7	.....	38	0	1.000
7	3.9 ± 1.0	.....	33	0	1.000
8	6.7 ± 3.8	.....	38	0	1.000
9	11.4 ± 7.1	.....	39	0	1.000
10	10.3 ± 6.4	46.5 ± 9.8	33	4	0.892
11	16.0 ± 10.3	33.4 ± 9.6	32	7	0.821
12	23.0 ± 14.9	32.2 ± 18.7	25	15	0.625
13	18.8 ± 8.9	31.1 ± 10.4	16	24	0.400
14	25.2 ± 8.6	28.7 ± 12.9	5	34	0.128
15	17.0 ± 0	20.4 ± 6.1	1	33	0.029
16	.....	15.6 ± 4.2	0	33	0.000

TABLE IV.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer W. W.

Stimulus Number	Time in seconds			Number			Frequency
	R	*W*	*X*	*R*	*W*	*X*	$R/(R+W+X)$
			Both eyes.				
7	5.1 ± 1.8	.....	.....	36	0	0	1.000
8	6.5 ± 4.0	.....	.....	42	0	0	1.000
9	7.3 ± 3.6	.....	.....	42	0	0	1.000
10	10.9 ± 7.6	.....	45.0 ± 0	41	0	1	0.976
11	17.1 ± 12.0	.....	63.8 ± 38.8	38	0	4	0.904
12	22.5 ± 15.8	.....	46.8 ± 17.3	33	0	10	0.767
13	34.9 ± 24.0	90.0 ± 0	41.7 ± 11.7	22	1	19	0.524
14	32.5 ± 17.8	63.0 ± 3.0	33.9 ± 14.0	13	2	27	0.309
15	34.0 ± 20.3	.....	30.0 ± 11.1	7	0	35	0.167
16	.....	.....	27.8 ± 10.6	0	0	36	0.000
			Left eye.				
6	6.0 ± 2.4	.....	.....	36	0	0	1.000
7	8.0 ± 4.1	.....	.....	36	0	0	1.000
8	8.1 ± 3.9	.....	.....	42	0	0	1.000
9	11.1 ± 6.6	.....	.....	42	0	0	1.000
10	16.4 ± 9.8	.....	38.5 ± 11.5	40	0	2	0.952
11	20.5 ± 13.0	.....	53.5 ± 16.3	31	0	11	0.738
12	20.9 ± 9.6	.....	31.2 ± 6.9	25	0	17	0.595
13	28.2 ± 14.3	.....	33.2 ± 8.8	12	0	30	0.286
14	41.4 ± 9.7	.....	29.3 ± 9.3	5	0	37	0.119
15	45.0 ± 0	.....	26.1 ± 8.3	1	0	41	0.024
16	.....	.....	20.6 ± 5.4	0	0	30	0.000
			Right eye.				
6	6.1 ± 3.1	.....	.....	36	0	0	1.000
7	5.9 ± 2.2	.....	.....	36	0	0	1.000
8	12.7 ± 10.6	.....	.....	42	0	0	1.000
9	7.5 ± 3.2	.....	.....	42	0	0	1.000
10	14.9 ± 11.0	26.0 ± 21.0	55.0 ± 0	39	2	1	0.929
11	17.5 ± 11.7	.....	43.6 ± 8.9	38	0	5	0.884
12	21.4 ± 17.8	.....	41.1 ± 9.9	30	0	12	0.714
13	19.9 ± 11.3	.....	32.6 ± 9.0	19	0	23	0.452
14	26.1 ± 16.0	.....	35.7 ± 14.8	15	0	27	0.357
15	18.3 ± 9.5	.....	26.0 ± 8.1	7	0	35	0.167
16	.....	.....	25.6 ± 8.4	0	0	32	0.000

TABLE IV–A.

Corrected Results.

A Summary Similar to Table IV but with Wrong Answers Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer W. W.

Stimulus Number	Time in seconds		Number		Frequency
	R	*X*	*R*	*X*	*R*/(*R*+*X*)
		Both eyes.			
7	4.5 ± 1.3	.....	34	0	1.000
8	4.2 ± 1.3	.....	35	0	1.000
9	5.3 ± 1.6	.....	35	0	1.000
10	6.8 ± 2.6	45.0 ± 0	35	1	0.972
11	12.6 ± 7.0	63.8 ± 38.8	34	4	0.895
12	17.6 ± 11.4	46.8 ± 17.3	30	10	0.750
13	23.2 ± 12.0	36.6 ± 6.7	19	17	0.528
14	24.2 ± 10.6	27.6 ± 8.0	11	23	0.324
15	23.2 ± 7.8	28.3 ± 7.1	6	33	0.154
16	.....	24.8 ± 8.0	0	33	0.000
		Left eye.			
6	6.0 ± 2.4	.....	36	0	1.000
7	6.2 ± 2.8	.....	33	0	1.000
8	6.5 ± 2.2	.....	33	0	1.000
9	8.7 ± 4.0	.....	40	0	1.000
10	13.0 ± 6.4	38.5 ± 11.5	36	2	0.947
11	18.9 ± 11.5	48.3 ± 18.0	30	10	0.750
12	19.7 ± 8.6	29.5 ± 7.3	24	16	0.600
13	28.2 ± 14.3	31.3 ± 8.3	12	28	0.300
14	41.4 ± 9.7	29.3 ± 9.3	5	37	0.119
15	45.0 ± 0	26.1 ± 8.3	1	41	0.024
16	.....	19.4 ± 4.3	0	28	0.000
		Right eye			
6	4.6 ± 1.3	.....	34	0	1.000
7	5.1 ± 1.5	.....	33	0	1.000
8	6.2 ± 1.7	.....	34	0	1.000
9	5.8 ± 1.5	.....	36	0	1.000
10	7.4 ± 2.2	55.0 ± 0	29	1	0.967
11	17.5 ± 11.7	43.6 ± 14.3	38	5	0.884
12	11.6 ± 7.5	41.1 ± 9.9	24	12	0.667
13	11.6 ± 3.3	29.6 ± 6.7	13	21	0.372
14	26.1 ± 16.0	26.4 ± 5.1	15	21	0.417
15	18.3 ± 9.5	24.3 ± 6.6	7	33	0.175
16	.....	22.2 ± 5.3	0	29	0.000

PART II.

NON-STEREOSCOPIC ACUITY TESTS UNDER TWILIGHT ILLUMINATION.

CERTAIN investigations by Piper [4] in the functions of the eyes have shown a mutual reinforcement of the two eyes when these were adapted to light of low intensity by a period of darkness, while the same eyes coming immediately from the light showed no such reinforcement. The test object in his work was a field of considerable extent, and the measure of sensitivity was the lowest brightness at which the field could be seen. At first, after coming from the light into the dark room, it was found that the lowest perceptible brightness was the same, whether one or two eyes were used. In the course of an hour in the dark the sensitivity of vision, measured by this criterion, increased enormously; and at the end of that period it was found that the lowest perceptible brightness for one eye was nearly or quite double that required for binocular vision.

This and other facts that have appeared from research in physiological optics have given rise to a theory of two-fold function of the retina. The anatomical representatives of the two functions are respectively the rods and cones, and the theory, briefly stated, follows:

(1) The cones of the retina are exclusively, or at least predominantly, functional at ordinary daylight intensities; and also below this to the point where colors cease to be differentiated as such.

(2) At this point the rods have exclusively assumed the function of vision, the cones dropping out by reason of their lower sensitiveness.

This theory is borne out by abundant evidence. A series of experiments upon the eye, extending through both these ranges of intensity, almost invariably shows that vision accords with different laws in the two regions. These two modes of vision are so distinct that they have received the respective designations, "daylight vision" and "twilight vision."

The present work was undertaken as supplementary to the work treated in Part I of this report, and the aim was to investi-

[4] Klin. Monatsbl. f. Augenheilk, 3, 1907, p. 357.

gate the same point under twilight illumination. It was conducted with the same apparatus and by the same methods as far as was consistent with this essential condition.

APPARATUS AND PROCEDURE.

Natural twilight is invariably a rapidly changing quantity, and, therefore, for purposes of experiment it is necessary to simulate it by artificial means which may be held in a constant state. This work was then necessarily performed under cover. It early appeared that the relatively short distances available in laboratory rooms of ordinary size were inadmissible for the purpose. The degree of convergence required of a pair of eyes looking through a prism binocular is greater by two factors than that required, at the same actual distance, of the unaided eyes. These factors are: (1) the ratio of the axial separation of the two objectives to that of the subject's eyes, and (2) the magnification of the glass. In the present case the product of these two factors (1.75×6) is 10.5. At a distance of 7 metres, with the glass, a (computed) degree of convergence is required corresponding to a distance of 67 cm., which in turn tends to induce accommodation for that distance. That such accommodation takes place to some extent is shown by the simple experiment of focussing the two limbs of the binocular separately and monocularly on an object at, say, 7 metres; then in attempting to use it with both eyes it will be found to be no longer in focus for the same object. Satisfactory refocussing was not practicable under the light conditions planned. Increasing the illumination and involving an additional loss of time waiting for the subject to readapt to the experimental condition was inexpedient. This detail of the problem was finally solved by finding a range of adequate length.

The work was actually carried out in one of the underground tunnels at Nela Park, constructed and used as a conduit for pipes and electric wires. A stretch of tunnel was available which easily made possible a range of 81.65 metres, measured from the eyes of the observer to the test object. The convergence demanded in the use of the binocular at this distance is equal to that required in ordinary vision at a distance of ($81.65/10.5 =$) 7.8 metres. The grade of accommodation corresponding to this distance and degree of convergence is well below the limit accepted in the practice of ophthalmology as negligible.

The clear space in the tunnel, left as a runway, has a width of 1.4 metres, and its height is sufficient to permit a man of average height to walk easily without stooping. The observations were made from a seated posture, one of the observers being somewhat too tall to stand comfortably in the tunnel. Signals were exchanged by means of buzzers between the experimenter and the observer.

The test object was illuminated by projecting upon it the much enlarged image of a highly illuminated disc of milk glass set in the side of a Thorington ophthalmological chimney. Within the chimney was a 40-watt tungsten filament vacuum lamp kept at a constant current. Over the lens which projected the image of the disc was placed a piece of blue glass known as "north skylight glass" which with the lamp used gave light of an approximate daylight color.

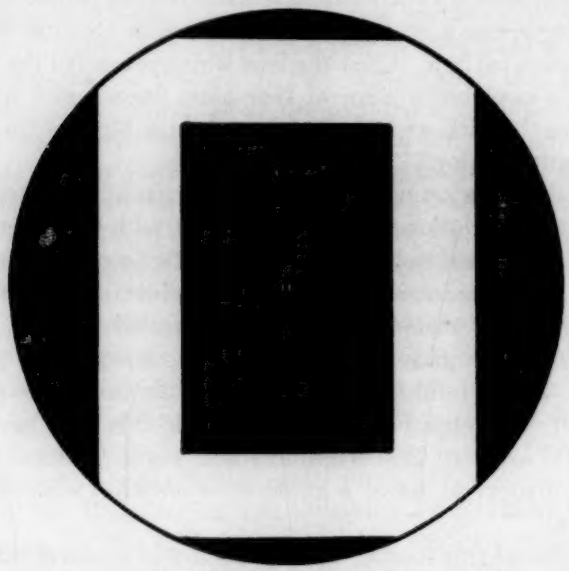
The illumination upon the test object from this device measured, at the conclusion of the experiments, with a Macbeth Illuminometer was found to be 0.011 metre candle (0.0012 foot candle). At this low illumination and with the white stripes of the test object the only visible objects, it was found difficult, in some cases, to get the glass oriented upon the object at all promptly. Further, actual outdoor twilight vision almost never occurs in this way. The object is almost always, in this case, seen upon a large field, of very low brightness and vague in detail, but sufficiently distinct to act as a guide in orientation with or without the glass.

To obviate this trouble a foreground was constructed. It was a frame of light boards having a central rectangular opening 1.26 metres high by 0.82 wide. The width of the sides, top, and bottom of the frame (about 30 cm.) made it large enough to fill the cross-section of the tunnel, 1.9 by 1.4 metres. This frame was painted white and hung at a distance of 15.5 metres from the observer. By a separate light it was illuminated to a point that made observation convenient, but never to appear brighter than the test object. This was left to the discretion of the individual observer, and for him it was kept always the same. While actually observing through the glass, the field appeared about as

shown in Fig. 6. For one of the observers, P. W. C., who wore glasses, the field was restricted so that the top and bottom were not simultaneously visible.

Before the begininng of each experimental session the subject was allowed to sit in his place under the experimental conditions in order that his eyes might become dark adapted. The time required for this was variable, from five to twenty minutes or so, the observer judging for himself what was adequate, guided largely by the disappearance of the subjective shadows which he

FIG 6.



Appearance of field.

perceived during this time, drifting about his visual field. After adaptation the test object was visible, but, of course, not resolvable, to the unaided eyes.

The experimental procedure was essentially the same as in the work already described in Part I of this report, except for the details mentioned. Table V is, in part, a repetition of Table I, Part I, the values under the head "Angle, minutes" having been recomputed and being the angles subtended by one of the white elements of the test object, without magnification, at the distance here used, 81.65 metres.

TABLE V.

Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.	Stimulus No.	Width cm.	Angle min.
0	12.00	5.05	8	6.00	2.53	16	3.00	1.26
1	11.00	4.63	9	5.50	2.32	17	2.75	1.16
2	10.09	4.25	10	5.04	2.12	18	2.52	1.06
3	9.25	3.90	11	4.62	1.95	19	2.31	0.97
4	8.49	3.57	12	4.24	1.79	20	2.12	0.89
5	7.78	3.28	13	3.89	1.64	21	1.94	0.82
6	7.14	3.00	14	3.57	1.50	22	1.78	0.75
7	6.54	2.76	15	3.27	1.38	23	1.64	0.69
8	6.00	2.53	16	3.00	1.26	24	1.50	0.63

RESULTS.

The average times of observation, for right, wrong and indeterminate answers, and for each size of test object used are given in Tables VI, VII, and VIII. The mean deviations appear following the mean values. The numbers of right, wrong and indeterminate answers for the various conditions are also given, and in the last column the net frequency of right answers. In considering this last, it is to be remembered that in the previous work the wrong answers were at most very few, and they were left totally out of consideration. However, in the present work, in the case of one observer, they were numerous enough to be of importance, and it was not thought permissible to drop them altogether.

Obviously a wrong answer results from judgment in the absence of correct vision of the object. Such judgment (since the two positions of the object represent two possibilities) would, in the long run, result in equal numbers of right and wrong answers. Therefore, there is, in probability, a right answer given in the absence of correct vision for every wrong answer returned under the same conditions, and the net number of right answers, or the number of "truly" right answers is taken as the number of rights minus the number of wrongs. For this reason the frequencies in Tables VI, VII, and VIII are computed as the ratios of the net number of right answers ("right" minus "wrongs") to the total number of experiments.

In preparing Tables VI-A, VII-A, and VIII-A, three groups of experiments were omitted from consideration:

(1) Those in which wrong answers were returned, (2) an equal number of those in which right answers were given, selected

so as to have, each for each, as nearly as possible, equal times with the corresponding " wrongs," and (3) those which proved, when Chauvenet's criterion was applied, to have improbably long times of observation. It happened in a few cases that there were more wrongs than rights, in which event all of both classes were dropped without further consideration. Chauvenet's criterion was applied separately to the group of " rights " remaining after the second deletion, and to the group of experiments with indeterminate answer (" crosses "), under each experimental condition. The times, numbers and frequencies were then computed from the results remaining. The results given in these tables are also shown graphically in Figs. 7, 8, and 9. It is to be added here that the results were also plotted without omissions exactly as they came, and the plots were carefully examined and compared with the ones appearing here. It was found that they differed in no essential particular and that the discussion and conclusions following apply equally well in either case.

DISCUSSION.

Examination of Figs. 7, 8, and 9 shows several characteristics which apply equally well to each of the three observers. It appears, on examining the upper plots in the three figures, that for each observer vision was better (the frequency of right answers higher) when both eyes were used than when either eye was used alone. This is true in various degrees, somewhat doubtful in the case of P. W. C.

If we turn to the times of observation (lower plots) we find that where the test object is relatively large, that is, where the frequency of right answers is near to 100 per cent., the time required for observation with both eyes is shorter than with either eye alone. The three modes of observation (right, left, and both eyes) tend to show the same order of superiority with reference to time that they do with reference to frequency. Somewhere in the region where the frequency is 100 to 50 per cent. there is a stretch where the time of " right " observation with both eyes is about equal to that with either eye alone. It is in this stretch that the observations with doubtful answers begin to appear in significant numbers, and their average times are longer in the case of both eyes than with either one alone. Somewhat farther down

the scale of certainty even the right answers tend to be longer in coming, definitely in the case of S. M. S., Fig. 8, stimulus No. 10, and indicated in the case of W. W., Fig. 9, Nos. 10, 11, 12. Still farther down, where the frequency is very low, or where, we will say, observation is "certainly uncertain," a tendency is shown for even the doubtful answers to be rendered in less time when both eyes are used. This shows clearly in Fig. 8, stimulus No. 12, and is indicated in Fig. 7, No. 12.

SUMMARY.

Under illumination of twilight intensity, observation through a prism binocular showed the following differences between binocular and monocular use of the same:

(1) With binocular observation the threshold is somewhat lower than with monocular observation with the better of the two eyes alone.

(2) When the test object is of such size that the judgments are preponderantly correct, the decision of the observer is arrived at in shorter time with binocular observation than with monocular.

(3) There seems to be reason to believe that this is also true in a negative sense. When the test object is very small and all or nearly all the judgments are indeterminate these also are to some extent rendered in shorter time with binocular observation than with monocular.

(4) With sizes of test object such that both right and indeterminate judgments appear in large numbers, the tendency is to spend more time in binocular observation than in monocular. This appears as an outspoken difference in time in the case of the indeterminate judgments, and in the case of the right judgments as a tendency for the time to become equal to or greater than the monocular time as the size of the test object is reduced. Compare with item (2) above.

It would seem, then, not only that vision with the glass is better and quicker with two eyes than with one, but also that the subject is readier or more willing, for some reason, to prolong his observations in the uncertain cases when he is observing binocularly.

TABLE VI.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with Their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer P. W. C.

Stimulus Number	Time in seconds			Number			Frequency $\frac{R-W}{R+W+X}$
	R	*W*	*X*	*R*	*W*	*X*	
			Both eyes.				
7	8.2 ± 3.1	.....	.....	46	0	0	1.000
8	16.3 ± 10.2	.....	92.0 ± 0	45	0	1	0.978
9	21.8 ± 14.9	.....	47.4 ± 15.1	34	0	12	0.739
10	33.3 ± 18.8	.....	62.7 ± 17.4	22	0	24	0.478
11	30.3 ± 11.5	.....	52.8 ± 17.4	9	0	37	0.195
12	51.0 ± 0	.....	48.7 ± 19.4	1	0	45	0.022
13	24.0 ± 0	.....	41.6 ± 12.3	1	0	45	0.022
			Left eye.				
5	5.8 ± 1.8	.....	.....	46	0	0	1.000
6	10.6 ± 4.9	.....	.....	46	0	0	1.000
7	14.5 ± 7.8	.....	65.8 ± 15.1	42	0	4	0.913
8	20.2 ± 11.3	.....	64.0 ± 23.7	40	0	6	0.870
9	26.9 ± 13.7	98.0 ± 0	53.9 ± 13.6	26	1	19	0.543
10	56.3 ± 20.6	.....	51.7 ± 15.6	14	0	32	0.304
11	35.5 ± 9.5	76.5 ± 67.5	48.9 ± 12.6	2	2	42	0.000
12	.....	.....	48.1 ± 15.8	0	0	42	0.000
			Right eye.				
6	8.2 ± 3.5	.....	.....	46	0	0	1.000
7	11.8 ± 6.3	.....	.....	46	0	0	1.000
8	18.7 ± 10.2	.....	61.5 ± 6.5	44	0	2	0.956
9	31.3 ± 16.2	48.0 ± 0	60.4 ± 14.7	34	1	11	0.717
10	33.9 ± 11.2	.....	48.6 ± 16.2	18	0	28	0.391
11	38.8 ± 22.3	.....	47.6 ± 17.2	12	0	34	0.261
12	.....	.....	50.8 ± 14.5	0	0	44	0.000

TABLE VI–A.

Corrected Results.

A Summary Similar to Table VI, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer P. W. C.

Stimulus Number	Time in seconds		Number		Frequency $\frac{R}{R+X}$
	R	*X*	*R*	*X*	
		Both eyes.			
7	6.9 ± 2.0	.....	41	0	1.000
8	9.7 ± 3.1	92.0 ± 0	35	1	0.972
9	14.6 ± 6.8	38.8 ± 7.6	29	10	0.744
10	33.3 ± 18.8	62.7 ± 17.4	22	24	0.478
11	30.3 ± 11.5	51.1 ± 16.0	9	36	0.200
12	51.0 ± 0	48.6 ± 19.4	1	45	0.022
13	.....	41.6 ± 12.3	0	45	0.000
		Left eye.			
5	5.0 ± 2.5	.....	40	0	1.000
6	7.9 ± 2.2	.....	38	0	1.000
7	9.7 ± 2.4	65.8 ± 15.1	34	4	0.895
8	16.3 ± 7.2	64.0 ± 23.7	37	6	0.860
9	22.4 ± 10.0	53.9 ± 13.6	23	19	0.548
10	56.3 ± 20.6	49.6 ± 14.4	14	31	0.311
11	.....	42.5 ± 6.9	0	35	0.000
12	.....	48.1 ± 15.8	0	42	0.000
		Right eye.			
6	6.5 ± 1.8	.....	39	0	1.000
7	8.3 ± 2.4	.....	39	0	1.000
8	15.0 ± 6.2	61.5 ± 6.5	39	2	0.951
9	30.9 ± 16.1	60.4 ± 14.7	33	11	0.750
10	33.9 ± 11.2	48.6 ± 16.2	18	28	0.391
11	38.8 ± 22.3	47.6 ± 17.2	12	34	0.261
12	.....	49.5 ± 13.6	0	43	0.000

TABLE VII.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*), and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer S. M. S.

Stimulus Number	Time in seconds			Number			Frequency $\frac{R-W}{R+W+X}$
	R	*W*	*X*	*R*	*W*	*X*	
			Both eyes.				
5	4.4 ± 1.1	.....	.....	24	0	0	1.000
6	7.9 ± 4.6	.....	.....	56	0	0	1.000
7	8.7 ± 4.0	.....	25.0 ± 0	55	0	1	0.982
8	20.3 ± 11.9	3 ± 0	38.6 ± 13.4	48	1	8	0.825
9	23.2 ± 15.0	.....	39.4 ± 16.8	27	0	29	0.482
10	35.8 ± 15.8	.....	32.7 ± 11.8	11	0	45	0.196
11	40.0 ± 0	36 ± 0	31.0 ± 12.7	1	1	54	0.000
12	.....	.....	25.7 ± 8.6	0	0	50	0.000
			Left eye.				
5	7.3 ± 3.3	.....	.....	56	0	0	1.000
6	11.4 ± 6.8	.....	.....	56	0	0	1.000
7	16.8 ± 8.8	.....	57.0 ± 23.3	53	0	3	0.946
8	20.3 ± 10.4	.....	38.6 ± 9.7	43	0	13	0.768
9	22.9 ± 12.5	13 ± 0	32.6 ± 12.8	22	1	33	0.375
10	25.2 ± 13.8	.....	27.6 ± 9.3	6	0	50	0.107
11	26.0 ± 3.0	.....	29.6 ± 11.5	2	0	54	0.036
12	.....	.....	33.3 ± 11.1	0	0	20	0.000
			Right eye.				
5	6.5 ± 2.8	.....	5.0 ± 0	55	0	1	0.982
6	9.2 ± 4.5	.....	.....	56	0	0	1.000
7	15.3 ± 10.0	.....	25.3 ± 4.4	53	0	3	0.946
8	19.3 ± 9.5	.....	39.8 ± 15.4	44	0	12	0.786
9	24.0 ± 13.7	.....	32.5 ± 13.8	23	0	33	0.410
10	27.4 ± 8.8	19 ± 0	30.3 ± 12.3	7	1	48	0.107
11	24.0 ± 10.7	.....	26.3 ± 8.7	3	0	53	0.054
12	46.0 ± 0	.....	31.9 ± 13.2	1	0	21	0.048

TABLE VII–A.

Corrected Results.

A Summary Similar to Table VII, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

Observer S. M. S.

Stimulus Number	Time in seconds		Number		Frequency $\frac{R}{R+X}$
	R	X	R	X	
		Both eyes.			
5	4.0 ± 0.7	.....	22	0	1.000
6	5.4 ± 1.8	.....	47	0	1.000
7	7.0 ± 2.2	25.0 ± 0	49	1	0.980
8	17.9 ± 9.4	38.6 ± 13.4	44	8	0.846
9	18.3 ± 9.7	33.2 ± 11.6	25	26	0.490
10	35.8 ± 15.8	32.7 ± 11.8	11	45	0.196
11	.....	27.2 ± 9.0	0	50	0.000
12	.....	24.2 ± 4.9	0	48	0.000
		Left eye.			
5	6.8 ± 2.8	.....	54	0	1.000
6	8.5 ± 3.9	.....	49	0	1.000
7	14.6 ± 6.6	57.0 ± 23.3	50	3	0.943
8	14.6 ± 5.3	38.6 ± 9.7	36	13	0.735
9	21.4 ± 10.8	27.5 ± 7.5	20	30	0.400
10	25.2 ± 13.8	27.0 ± 8.8	6	49	0.109
11	26.0 ± 3.0	27.4 ± 9.4	2	52	0.037
12	.....	33.3 ± 11.1	0	20	0.000
		Right eye.			
5	5.2 ± 1.3	5.0 ± 0	48	1	0.980
6	7.3 ± 2.4	.....	49	0	1.000
7	9.5 ± 3.2	25.3 ± 4.4	44	3	0.936
8	15.0 ± 5.2	39.8 ± 15.4	38	12	0.760
9	16.9 ± 4.9	26.5 ± 7.2	21	30	0.412
10	28.7 ± 9.2	25.8 ± 7.6	6	43	0.122
11	24.0 ± 10.7	25.0 ± 7.4	3	51	0.056
12	46.0 ± 0	31.9 ± 13.2	1	21	0.045

TABLE VIII.

Summary of Results.

A Tabulation of the Number of Right (*R*), Wrong (*W*) and Indeterminate (*X*) Answers for Each Size of Stimulus Presented; the Average Length of Time Required for Each of the Above Sets of Answers, Together with their Mean Deviations; and the Statistical Frequency of the Occurrence of Right Answers.

Observer W. W.

Stimulus Number	Time in seconds			Number			Frequency $\frac{R-W}{R+W+X}$
	R	*W*	*X*	*R*	*W*	*X*	
			Both eyes.				
7	6.6 ± 2.0	.....	.....	52	0	0	1.000
8	8.0 ± 3.0	.....	.....	52	0	0	1.000
9	12.9 ± 6.4	.....	32.0 ± 0	51	0	1	0.981
10	23.7 ± 12.1	.....	50.9 ± 6.9	41	0	11	0.789
11	26.7 ± 14.5	.....	53.6 ± 16.9	27	0	25	0.519
12	29.6 ± 11.3	33.0 ± 16.0	53.8 ± 14.0	17	2	33	0.289
13	50.2 ± 11.4	38.3 ± 12.0	51.4 ± 16.1	5	6	41	0.000
14	39.3 ± 16.4	41.4 ± 20.5	49.7 ± 14.2	3	5	32	0.000
			Left eye.				
6	5.7 ± 1.6	.....	35.0 ± 0	51	0	1	0.981
7	9.3 ± 4.7	.....	35.0 ± 0	51	0	1	0.981
8	10.3 ± 3.6	.....	35.4 ± 9.6	45	0	7	0.865
9	18.6 ± 11.1	21.0 ± 0	44.1 ± 12.3	41	1	10	0.770
10	17.9 ± 6.9	.....	37.1 ± 12.0	28	0	24	0.538
11	26.9 ± 13.8	38.0 ± 28.0	37.2 ± 10.9	15	2	35	0.250
12	29.5 ± 9.0	24.5 ± 16.3	40.3 ± 11.8	6	6	40	0.000
13	17.0 ± 0	56.0 ± 10.0	40.8 ± 11.6	1	3	29	0.000
			Right eye.				
7	7.5 ± 2.3	.....	.....	52	0	0	1.000
8	12.3 ± 5.5	.....	.....	52	0	0	1.000
9	16.9 ± 8.3	.....	37.0 ± 14.0	49	0	3	0.942
10	21.9 ± 9.8	.....	40.4 ± 10.0	33	0	19	0.635
11	28.7 ± 12.6	36.0 ± 20.0	41.5 ± 14.2	18	3	31	0.288
12	32.4 ± 15.3	18.7 ± 6.0	43.0 ± 11.2	7	7	38	0.000
13	38.0 ± 8.0	32.8 ± 15.2	42.2 ± 11.5	2	4	40	0.000
14	.....	37.6 ± 23.1	38.7 ± 9.1	0	5	33	0.000

TABLE VIII–A.

Corrected Results.

A Summary Similar to Table VIII, but with Wrong Answers and an Equal Number of Right Answers with Corresponding Times Omitted, and Huge Time-values Eliminated by the Application of Chauvenet's Criterion.

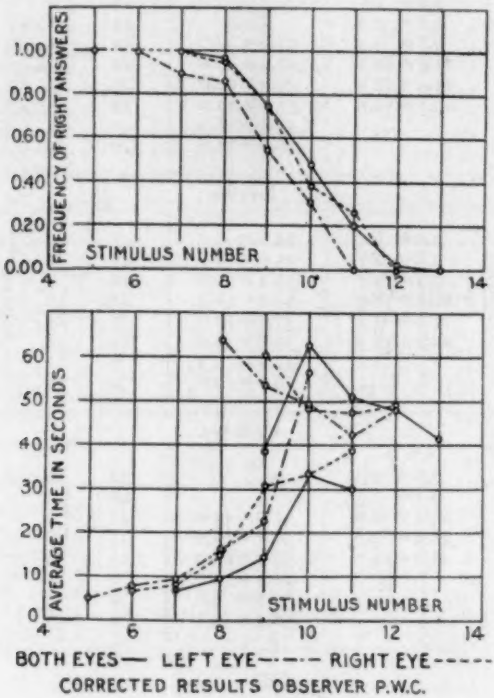
Observer W. W.

Stimulus Number	Time in seconds		Number		Frequency $\frac{R}{R+X}$
	R	X	R	X	
		Both eyes.			
7	5.8 ± 1.3	.....	46	0	1.000
8	6.6 ± 1.6	.....	45	0	1.000
9	9.8 ± 3.3	32.0 ± 0	44	1	0.978
10	21.8 ± 10.1	48.3 ± 6.0	40	10	0.800
11	24.4 ± 12.2	49.4 ± 14.0	26	23	0.530
12	29.1 ± 10.5	53.8 ± 14.0	15	33	0.312
13	.....	51.4 ± 16.1	0	41	0.000
14	.....	46.7 ± 11.6	0	30	0.000
		Left eye.			
6	5.0 ± 0.9	35.0 ± 0	47	1	0.979
7	7.6 ± 2.7	35.0 ± 0	47	1	0.979
8	9.3 ± 2.7	35.4 ± 9.6	42	7	0.857
9	16.1 ± 8.9	44.1 ± 12.3	38	10	0.792
10	14.0 ± 3.4	37.1 ± 12.0	23	24	0.489
11	25.2 ± 11.5	35.8 ± 9.8	13	34	0.276
12	.....	37.2 ± 9.3	0	37	0.000
13	.....	39.1 ± 9.8	0	28	0.000
		Right eye.			
7	7.5 ± 2.3	.....	52	0	1.000
8	9.5 ± 2.5	.....	45	0	1.000
9	13.4 ± 4.6	37.0 ± 14.0	43	3	0.935
10	21.9 ± 9.7	36.1 ± 6.6	33	16	0.674
11	28.0 ± 11.7	39.7 ± 13.0	15	30	0.333
12	.....	41.4 ± 9.6	0	36	0.000
13	.....	39.0 ± 8.6	0	37	0.000
14	.....	38.7 ± 9.1	0	33	0.000

COMPARISON OF RESULTS—DAYLIGHT AND TWILIGHT.

The absolute values of the thresholds for the various conditions may be interpolated from the upper plots of Figs. 3, 4, and 5 of Part I and Figs. 7, 8, and 9 as the point on the stimulus scale at which the right judgments are 50 per cent. of the whole number of experiments. The values for binocular vision will be sufficient for the present purpose, and they are stated in Table IX. Re-

FIG 7.



ferring to Table I, Part I, or to Table V, as the case may be, gives the corresponding angle, which, multiplied by the magnification factor 6, gives the visual angle. The reciprocal of this angle in minutes is visual acuity on the Snellen scale.

It will be seen from the table that under daylight conditions the three observers agreed quite closely in the value of their binocular sensitivity, while under the dim light the variation is

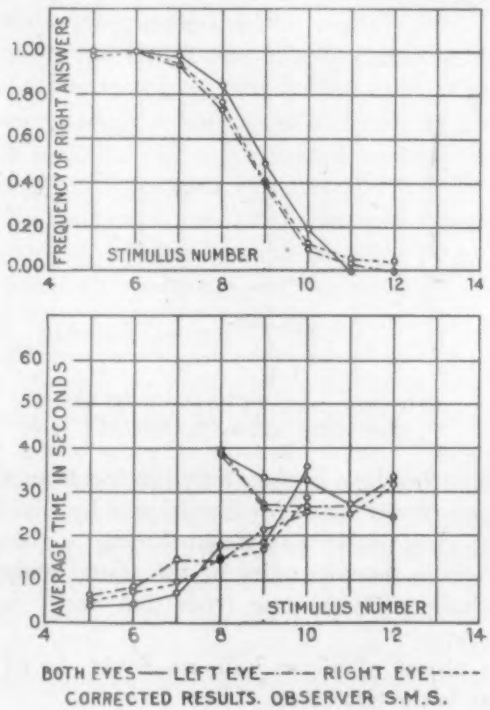
relatively much larger, although in either case the deviation is not wide. The mean acuity for the daylight condition is, of course, much the larger, by a ratio of 15.6 to 1.

TABLE IX.

The Binocular Threshold Value and Visual Acuity for Daylight and Twilight Conditions.

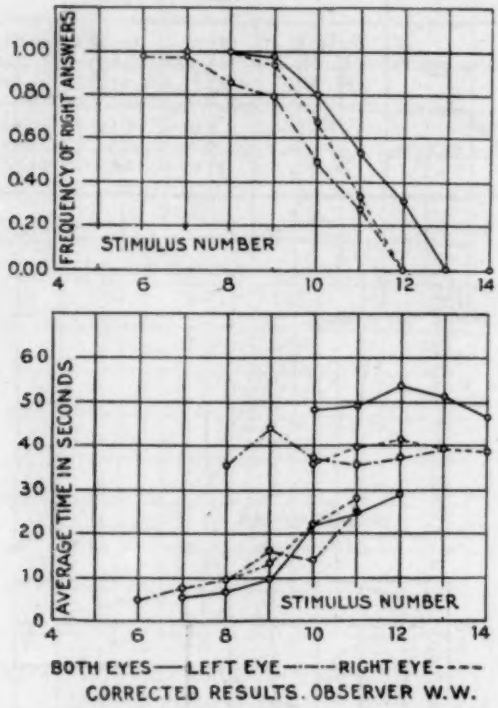
Conditions	Observer	Stimulus number	Angle min.	X 6	Visual acuity (Snellen)
Daylight Distance 956 m	P. W. C.	13.3	0.135	0.810	1.23
	G. H.	13.5	.133	.798	1.25
	W. W.	13.1	.138	.828	1.21
Twilight Distance 81.65 m	P. W. C.	9.9	2.14	12.84	0.078
	S. M. S.	9.0	2.32	13.92	0.072
	W. W.	11.0	1.93	11.58	0.086

FIG 8.



The object just resolvable by unaided vision under daylight condition is only 6 times the size of the object just resolvable through the 6-power glass under the same conditions, and probably less than this by a substantial amount, because of the absorption of light by the glass parts and the inevitable tremor of the glass; the latter especially, to no inconsiderable degree, reduces the effectiveness of the magnification. The object just resolvable

FIG 9.



under twilight conditions is, therefore, not less than 2.6 (15.6/6) times as large as is necessary for it to be seen by unaided vision in full daylight. The problem of vision through a glass under twilight conditions is then, in point of the visual magnitudes considered, a wholly different one from that under full daylight, in several respects:

(1) The object of vision will, no doubt, be of a different practical class in the two cases.

(2) The much lower resolving power of the eye and hence the much larger visual angles considered under twilight conditions, no doubt, could be shown to make certain inherent disadvantages of the glass of less importance. In particular, it is quite probable that a higher magnifying power could be used, before the benefit of the increased magnification would be fully offset by the increase in the effect of unsteadiness thereby engendered; and also that higher errors in the optical parts, both spherical and chromatic, would be tolerable, and hence objectives of larger diameter available with a corresponding increase in the emergence pupil (up to the maximal diameter of the eye pupil) and in the amount of light. The present work, having been conducted in the two cases with the identical instrument, does not show what the relative visual effectiveness might become with two different instruments of optimal design for the respective conditions; nor does it attempt to make an estimate of the relative practical value of the glass under the two conditions.

In discussing the time values it was stated in Part I of this report, as applying to that portion of the work, that the slightly larger frequency of right judgments in binocular vision was offset or at least rendered indecisive as experimental evidence by the greater time required for observations. To find out whether, on the whole, the increased time was disproportionately large as compared with the difference in the certainty of vision the data were treated in a different way, and the results of this computation, applied both to the daylight and the twilight data, are set down in Table X.

For each observer the region of the stimulus scale was selected which included practically all of the stimuli upon which both right and doubtful answers were returned. For each mode of observation identical stimuli were chosen and the number of experiments on each stimulus is the same. The figures in the table apply in every case to all of the experiments, so that each section of the table shows the "performance" of the observer with respect to identical groups of varied stimuli in the three modes of observation. The last column of figures gives the results obtained, in each case, by dividing the aggregate time of observa-

tion for all experiments by the net number of right judgments ("rights" minus "wrongs") and is, therefore, a measure of the efficiency—or rather of the inefficiency—of the particular mode of observation.

Under full daylight, it will be remembered, observer P. W. C. gave distinctly poorer results in every respect with binocular observation. For the other two it is shown in the last column of Table X that the increased binocular frequency was purchased by relatively greater expenditure of time—definitely in the case of W. W. (as 42.7 to 46.3), and perhaps doubtfully in the case of G. H. (as 35.0 to 35.8). The "efficiencies" of binocular vision, taking the results from the better eye as a base, are for full daylight: for P. W. C., 83.5 per cent.; for W. W., 92 per cent.; and for G. H., 98 per cent.

In the case of twilight vision the figures tell a different story, for while the whole time of binocular vision is either less or very slightly more than in the better of the two monocular cases, the last column shows that for all three observers the total time is smaller, as compared with the number of right answers. The "efficiencies" of binocular observation for twilight conditions, on the same basis as in the last paragraph, are: for P. W. C., 108 per cent.; for W. W., 123 per cent.; and for S. M.S., 104 per cent.

It is perhaps taking too much for granted to assume, as the foregoing does at least by implication, that increased time spent in observation would lead to a proportionate increase in the frequency of correct vision. In all probability it would not, and it is not possible to state the direction in which such an assumption would err. It would seem, however, that this manner of comparison shows pretty clearly an advantage of the binocular glass over the monocular in its use in light of low intensities under conditions comparable to those of these experiments. It would also seem quite permissible to accept the foregoing method of interpreting the results as supplementary to the more detailed treatment which has gone before, especially when the last-mentioned (as in the daylight results) renders an ambiguous verdict.

TABLE X.

Average Times of Observations for Comparing Binocular with Monocular and Daylight with Twilight Observations.

		Number		$R-W$ Per cent.	Average time		Total time per $(R-W)$
		$R-W$	All		All	$(R-W)$	
Full Daylight.							
P. W. C.,	Both	148	246	60.2	25.7	16.0	42.7
Stimuli,	Left	166	246	67.5	24.1	15.9	35.7
No. 10–No. 15,	Right	105	246	42.7	28.2	17.2	66.0
W. W.,	Both	150	252	59.5	27.6	20.0	46.3
Stimuli,	Right	145	252	57.5	24.6	18.7	42.7
No. 10–No. 15,	Left	114	252	45.2	26.8	21.1	59.1
G. H.,	Both	153	246	62.2	22.2	16.0	35.8
Stimuli,	Left	149	246	60.6	21.2	14.4	35.0
No. 10–No. 15,	Right	112	246	45.5	23.9	18.2	52.6
Twilight (0.0012 Foot-candle)							
P. W. C.,	Both	157	276	56.9	33.4	18.5	58.7
Stimuli,	Right	153	276	55.4	35.0	22.6	63.1
No. 7–No. 12,	Left	121	276	43.8	39.2	23.4	89.4
W. W.,	Both	186	260	71.5	27.1	17.2	37.9
Stimuli,	Right	149	260	57.3	26.8	17.5	46.8
No. 8–No. 12,	Left	126	260	48.5	27.1	16.1	55.9
S. M. S.,	Both	195	336	58.0	22.6	14.8	39.0
Stimuli,	Right	185	336	55.1	22.3	16.1	40.5
No. 6–No. 11,	Left	181	336	53.9	23.4	17.1	43.4

(To be concluded.)

Important Vegetable Acids from Benzene. (*Amer. Chem. Soc. News Service*, Bulletin 252.)—Announcement has just been made by John M. Weiss and C. R. Downs, inventors and patentees, of a method by which tartaric, citric, lactic and succinic acids can be prepared from benzene at prices capable of competition with the natural products. The starting point is the production of maleic acid by the joint action of air and benzene under the influence of a catalyst, and from this acid those above mentioned can be obtained. Maleic acid has long been known as a natural product but its extraction has been too costly to consider it as a raw material for any commercial article. The synthetic production of tartaric acid will meet the possible diminution of the natural supply due to the cessation of wine-making in this country. The United States has been producing about ten million pounds of cream of tartar per year and about a million pounds of tartaric acid. H .L.

The Relation Between Uranium and Radium. SODDY. (*Phil. Mag.*, October, 1919, p. 483.)—The growth of radium in three kilograms of uranium has been studied for a period of ten years and again in .4 kilogram (note = four-tenths kilogram) for more than twelve years. In the larger quantity the total radium formed amounts to 242×10^{-12} gr. A quantity of radium as small as 10^{-12} gr. can be measured accurately. In both investigations the mass of radium formed is proportional to the square of the time during which it has been forming, thus in seven years 49 times as much will be developed as in one year.

G. F. S.

Hydro-electric Survey of India. (*Nature*, December 4, 1919.)—In this matter India is much behind other parts of the British Empire. Canada has installations for 148 watts per inhabitant. The corresponding number for Australia is 62; for South Africa, 57; for the British Isles, 33; while for India it is less than one. The total brake-horsepower of all kinds in India is 1,153,638 plus what is developed in some collieries and rice mills. Hydro-electric development is complicated by the uneven distribution of rainfall throughout the year, and by the holding of mountain regions with water power by uncivilized tribes.

G. F. S.

Competitive Exhibition of Machines and Materials Used in the Building Trades. (*La Nature*, December 13, 1919.)—At the Lyons Fair of March, 1920, there will be a competition between such machines, materials and products as represent progress in advance of what existed before the war. Machines will run under working conditions.

Such an exhibition will be timely in view of the hundreds of thousands of buildings destroyed in France as a result of the invasion by the Huns.

At this fair in 1919 the United States was represented on the program of speakers by Professor Fletcher (Pennsylvania State College) and by other members of the Faculty of the A. E. F. University at Beaune.

G. F. S.

Production of Iron in Italy.—According to the Italian Metallurgical Association, the ores obtained in Italy are about exhausted. Hitherto the chief source of iron ore has been in Elba. The cost of mining is, however, continuously on the increase, as the deposits are under the sea. Under the urge of the war vigorous search was made for new bodies of ore. At Val di Cogne, near the French border, six million tons were discovered, and in Sardinia an equally important deposit was located. These new resources cannot do more than postpone Italy's dependence for her iron upon other nations.

G. F. S.

BRANNERITE, A NEW URANIUM MINERAL.*

BY

FRANK L. HESS, A.B., and ROGER C. WELLS, Ph.D.

United States Geological Survey.

In 1915 S. M. Ballard sent to one of the writers a highly radioactive mineral that had been obtained from gold placers worked by Henry Sturkey in Stanley Basin in the central part of Idaho. Later other material was sent to the Survey by Mr. Sturkey. Mr. Sturkey's placer is near the head of Kelley Gulch, said to be in granite cut by pegmatites, and it is in the pegmatites that the source of the mineral is probably to be found.

In 1916 Robert N. Bell published a half-tone of a radiograph [1] made with the mineral by A. G. Van Eman, who thought it to be euxenite, with which it is related in composition and which it resembles in color and texture.

The mineral received is in grains, part of which are prisms and most of which show a prismatic tendency (see Fig. 1). They are a brownish yellow on the outside but the visible weathering has extended to a depth not exceeding the thickness of paper. Inside they are brilliant black, with a choncoidal fracture and no sign of cleavage. Polished specimens examined under reflected light show the mineral to be remarkably homogeneous. It is, however, traversed by minute cracks that are in part filled by quartz that undoubtedly accounts for the SiO_2 in the analysis. Although to the eye the mineral is an opaque black, under the microscope very thin chips allow sufficient yellowish green light to pass to make possible optical measurements. The streak is a dark greenish brown. The hardness is about 4.5 as the mineral will scratch apatite but will not scratch orthoclase.

The crystals are not perfect enough to allow a determination of the crystal form, but their shapes suggest that they may be orthorhombic or tetragonal. However, E. S. Larsen determined it to be isotropic with an index of $n_{Li} = 2.26 \pm 0.02$ and $n_{Na} = 2.30 \pm 0.02$. It seems probable that it is an isometric paramorph after either a tetragonal or an orthorhombic form as many of the

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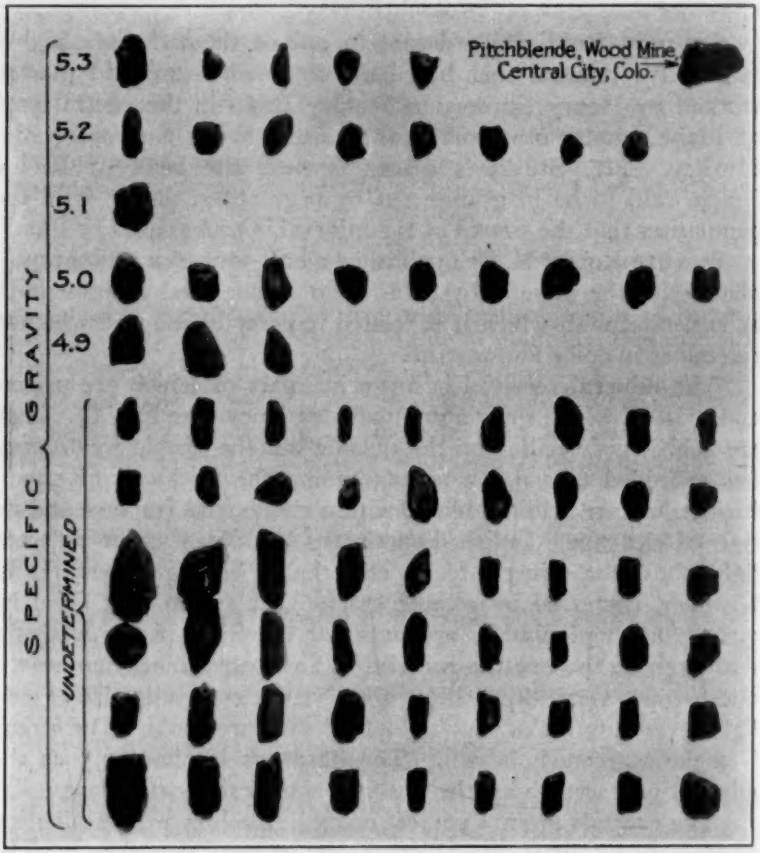
[1] Sixteenth Ann. Rept. Mine Inspector of Idaho (1915), Boise, pp. 29, 30.

complex pegmatitic uranium minerals seem to be. It will be noted in the tables given on other pages of this article that all but one of the minerals (hielmite) are isotropic. Yttrocrasite shows birefringent particles and is probably a mixture. Also like

FIG. 1.



Brannerite pebbles and a piece of pitchblende mounted on a card to test comparative radioactivity. Slightly reduced. See figure on opposite page.

nearly all of the complex pegmatitic minerals, the new mineral is variable in composition and the specific gravity of the specimens tested ranged from 4.5 to 5.43, as determined with the Joly balance. The specimens analyzed had a specific gravity of 5.42 (by pyknometer).

The radioactivity of the specimens of different specific gravities showed slight differences as tested by the exposure of a

FIG. 2.

Radiograph made by the minerals shown in figure 1. They were mounted on thin cardboard which was laid on the sensitive film of a photographic plate for 48 hours. A print was photographed through a prism in order to make comparison easier.

photographic plate. Those having the highest specific gravity appeared most active (see Fig. 2). The material was not tested in an electroscope. Attention may be called to the advantages of making a radiograph of various specimens in a case of this

sort before proceeding with the analysis, as it may be seen from Fig. 2 that some of the pieces were comparatively inactive, and pieces with a like content of uranium or thorium, or both may be readily selected. Two of the least active pieces from the seventh row (Fig. 2) gave on analysis 35.0 per cent. TiO_2 compared with 39.0 per cent. in the best material.

If in quantity the mineral would be of value as a source of radium, but probably only a few pounds could be obtained even at a prohibitive cost.

CHEMICAL ANALYSIS.

Our thanks are due to Mr. W. C. Wheeler for preliminary chemical determinations on the mineral. Mr. Wheeler established the presence of uranium and suggested the separation of titanium and uranium by hydrolysis, as finally carried out.

The mineral is slowly decomposed by treatment with concentrated sulfuric acid, or by hydrofluoric and sulfuric acids. It is more convenient, however, to bring it into solution by gentle fusion with acid sodium sulfate. On dissolving the melt in cold water, or dilute sulfuric acid, there remains a small residue consisting of silica, unattacked mineral, and sulfates of lead, barium and strontium, which was analyzed separately.

Various methods of analysis were tried, using principally the acid sulfate solution, but the unusual association of elements made the analysis largely a process of successive approximations. Each precipitate obtained was tested for impurities and if an admixture was found the method of analysis was modified accordingly.

It was thought at one time that the ammonium carbonate treatment could be relied on to separate the main constituents, uranium and titanium, but so much titanium was carried into the filtrate with the uranium in this process that it was decided to separate the titanium by hydrolysis. The precipitate and filtrate were then further analyzed separately.

For the hydrolytic separation of titanium the sulfate solution was treated with hydrogen sulfide, neutralized, freed from hydrogen sulfide with a stream of carbon dioxide, and finally diluted and boiled after the addition of considerable ammonium sulfate.[2]

In one analysis 3.1 per cent. of rare earths was found in the titanium separated as described and 5.0 per cent. in the uranium

[2] Hillebrand, W. F., U. S. Geol. Survey, Bull. 422, 137 (1910).

portion. In another analysis the total rare earths separated directly, first as fluorides and finally as oxalates, amounted to 8.0 per cent.

The filtrate from the titanium was precipitated twice with ammonium hydroxide, leaving calcium in solution. The hydroxides were dissolved in hydrochloric acid, evaporated nearly to dryness, taken up in hydrofluoric acid and the rare earths filtered off. After removing hydrofluoric acid with sulfuric acid, precipitating with ammonia, and dissolving the hydroxides in nitric acid, the remaining elements, chiefly uranium, were subjected to the ammonium carbonate treatment and uranium was finally separated and weighed as pyrophosphate.

The stage of oxidation of the uranium in the mineral was determined separately by decomposition with dilute sulfuric acid in a closed glass tube containing carbon dioxide at 225° C. and subsequent titration with potassium permanganate. It was assumed in calculating the proportion of UO_2 that all the iron of the mineral was in the ferrous condition. The only ground for this assumption is the fact that iron is more easily reduced than uranium, so that the existence of any uranous oxide would imply the absence of ferric oxide. However, the state of oxidation of the iron cannot be regarded as determined. The coating on the grains contained some ferric oxide which could only be removed by carefully chipping off the exterior and selecting the jet black pieces. A determination of iron as Fe_2O_3 on unselected material gave 3.7 per cent., whereas the value obtained on the best selected material was 3.0 per cent., or 2.7 per cent. FeO. Iron seems to be an essential constitutent of the mineral. In the extended analysis iron had to be determined in the titanium portion, in the ammonium carbonate precipitate, and in the uranium precipitate.

Thorium was determined in the mixture of rare earths by the sodium thiosulfate method. The ignited oxide was white, and pure as far as could be determined. The yttrium earths were estimated by their solubility in a solution of sodium sulfate. They were a buff color after ignition and gave by conversion of the oxides to sulfates, an average atomic weight of 151, a weight so great that probably erbium or ytterbium or both are present. Lack of time prevented a thorough investigation of the rare earths. No cerium earths could be detected. Water and carbon dioxide were weighed in absorption tubes after heating the min-

eral in a boat in a hard glass tube in a current of dry air. A small correction was applied based on the results of blank determinations run similarly. No magnesium, tin, tungsten, tantalum, columbium, molybdenum, vanadium, copper, or fluorine could be detected.

An attempt was made to heat the mineral, mixed with carbon, in a stream of chlorine and make a fractional condensation of the volatile chlorides. A complete separation of the uranium and titanium was not accomplished, but the non-volatile residue in the boat was found to contain calcium, rare earths chiefly of the yttrium group, iron, and a little uranium.

An attempt was also made to detect helium but without success. On heating 5 grammes of the mineral with acid sodium sulfate in a vacuum a few cubic centimetres of gas were obtained —largely sulfur dioxide, which was probably generated by the action of the UO_2 on the sulfuric acid. Nearly all of the gas was soluble in a solution of sodium hydroxide and what remained gave only nitrogen lines, as far as could be determined, when examined in a Pluecker tube.

The various determinations led to the following results:

Composition of the Mineral from Stanley Basin.

(R. C. Wells, analyst.)

	Per cent.	Molecular values.
SiO_2	.6	.010
TiO_2	39.0	.488
FeO	2.9	.040
CaO	2.9	.052
UO_2	10.3	.038
UO_3	33.5	.116
ThO_2	4.1	.015
Ce_2O_3	none	
Yt_2O_3, etc.[1]	3.9	.011
ZrO_2	.2	.001
PbO	.2	.001
BaO	.3	.002
SrO	.1	.001
H_2O	2.0	.111
CO_2	.2	.005
Fe_2O_3, Al_2O_3, P_2O_5	trace	
	100.2	

Specific gravity, 5.42.

[1] Average molecular weight 350.

CALCULATION OF FORMULA

The following combinations in molecular values seem logical:

FeO	.040	UO_2	.038	CO_2	.005
CaO	.052	ThO_2	.015	SiO_2	.010
BaO	.002	ZrO_2	.002	TiO_2	.488
SrO	.001		—		—
PbO	.001		.055		.503
	.096				

This leaves $Yt_2O_3 = 0.011$, $UO_3 = .116$, and $H_2O = .111$ ungrouped. On this basis the mineral may be simplified to:

RO	.096		8.7
Yt_2O_3	.011		1.0
RO_2	.055	or	5.0
UO_3	.116		10.5
TiO_2	.503		45.7
H_2O	.111		10.1

Without any further combination this yields the following approximate formula:

$$9\ RO.\ Yt_2O_3.\ 5\ RO_2\ 11\ UO_3.\ 46\ TiO_2.\ 10\ H_2O.$$

The figures for RO and UO_3 are not very near whole numbers, but this need cause no disappointment as the whole calculation rests on the assumption that the iron is in the ferrous condition. Although this assumption has certain analogies to support it and is given preference, it would not be entirely unreasonable to assume that part or all of the iron is in the ferric condition. The question cannot be settled experimentally in the presence of uranium in two stages of oxidation. If all of the iron is assumed to be present as ferric iron the following percentages and molecular values are obtained in place of those first given:

	Per cent.	Molecular values.
FeO	None	—
Fe_2O_3	3.2	.020
UO_2	18.4	.068
UO_3	25.1	.089

Appropriate grouping now leads to the approximate formula:

$$2\ RO.\ R_2O_3.\ 3\ RO_2.\ 3\ UO_3.\ 18\ TiO_2.\ 4\ H_2O.$$

The bases are apparently present as titanates, metatitanates, or uranotitanates, but an exact evaluation of the relative pro-

portions of these compounds is obviously very difficult and hardly appears practicable in view of the uncertainty concerning the stage of oxidation of the iron and uranium. There is more TiO_2 present than is required to form normal titanates of all the bases, but not enough to form metatitanates without taking some uranium as the basic radicals UO and UO_2. To secure an exact balance any excess of TiO_2 may be reduced to the form of a titanyl metatitanate $TiO.TiO_3$.

The results below are presented for illustration as one of the possibilities along this line with little to recommend it over others that could be given.

Oxide	Molecular value	Metatitanate	TiO_3 required
RO	.096	$R TiO_3$	.096
Yt_2O_3	.011	$Yt_2(TiO_3)_3$	.033
ThO_2	.016	$Th(TiO_3)_2$	.032
ZrO_2	.001	$Zr(TiO_3)_2$	.002
UO_2	.038	$UO TiO_3$	.038
UO_3	.116	$UO(TiO_3)_2$	.232
TiO_2	.070	$TiO TiO_3$	.070
			.503

On this basis the mineral may be represented as a hydrated metatitanate of various bases, thus: $(Ca, Fe, UO, TiO)TiO_3 + (Th, Zr, UO)(TiO_3)_2 + Yt_2(TiO_3)_3 + H_2O$. Without implying exact molecular ratios the proportions of these four species would be about 6, 8, 1, 3, respectively. It should be remembered, however, that the stage of oxidation of the iron is unknown and this ignorance introduces uncertainty in these proportions. Nor is it known whether minerals of this kind should be considered as mixed crystals, solid solutions, or salts of complex acids, although in one of these suppositions may lie the correct explanation of their composition.

Analyses of the known complex uranium minerals have been arranged in the tables following so that the uranium content increases progressively toward the end of the series. The newly described mineral from Idaho is designated as *brannerite*.

It will be seen that the new mineral contains more uranium than any other except the pitchblendes. Unlike most of the others it contains no tantalum or columbium and is very high in titanium.

Comparative Analyses of the Complex Uranium Minerals.

(Arranged in the order of their uranium content.)

Name	Risörite	Yttrialite	Zirkelite	Microlite	Yttrotantalite	Yttrocrasite	Priorite	Naëgite	Sipylite
Page, Dana's System	App. 3, p. 68	512	App. 1, p. 75	728	739	App. 2, p. 112	App. 2, p. 17	App. 2, p. 73	734
Analyst	O. Hauser	J. B. Mackintosh	G. T. Prior	Dunnington	Rammelsberg	C. H. Warren	G. T. Prior	Haga	W. G. Brown
Crys. Form[a]		A	I	I	O	O	O	T	T
Isot. or bif.[b]	Isot.	Isot.	Isot.	Isot.	Isot.	Isot to bif.	.....	Isot.	Isot.
Indices	2.05	1.758	2.19	1.930	2.15	2.13	.....	1.818	2.06
Sp. G.	.....	4.575	4.741	5.656	5.425	4.8043	.....	4.09	4.89
Ta_2O_5	4.00	.....	.....	68.43	46.25	Trace	.....	7.69	.....
Cb_2O_5	36.21	.....	.....	7.74	12.32	Present	36.68		48.66
TiO_2	6.00	.....	14.95	.....	.....	49.72	21.89	.....	.....
UO_2	Undet.	.....	1.40	.....	1.61	1.98	0.49	.....	3.47[h]
UO	.....	0.83	.....	1.59	.....	0.64	2.14	3.03	.....
Ce_2O_3	2.88[c]	1.86	2.52	0.17[k]	2.22	2.92	4.32	.....	1.37
$(Di, La)_2O_3$	.....	2.94[c]	.....	.....	.....	.....		.....	7.98
Y_2O_3	36.28	46.50[f]	0.21[j]	0.23	10.52	25.67	17.11	9.12	27.94[l]
Er_2O_3		.....	.....	.....	6.71			.....	
ThO_2	Undet.	12.00	7.31	.....	.....	8.75	0.61	5.01	.....
ZrO_2	.....	.....	52.89	.....	.....	.....	.....	55.30	2.09
CaO	1.93	0.60	10.79	11.80	5.73	1.83	4.12	.....	2.61
MgO	.....	.....	0.22	1.01	.....	Trace	0.22	.....	0.05
WO_3	.....	.....	.....	0.30	2.36	1.87	.....	.....	0.16
SnO_2	Undet.	.....	.....	1.05	1.12	.....	0.29	.....	0.08
FeO	2.61	2.89	7.72	.....	3.80	.....	5.63	.....	2.04
Fe_2O_3	1.20	.....	.....	0.29	.....	1.44	.....	.....	.....
MnO	.....	0.77	.....	.....	.....	0.13	0.19	.....	Trace
PbO	Undet.	0.85	.....	.....	.....	0.48	.....	.....	.....
H_2O-	7.11	0.79[g]	1.02[g]	1.17	6.31	4.36	3.69	.....	3.19
H_2O+						0.10			
X	0.90[d]	.....	.....	.....	.....	0.68[i]	.....	.....	Trace[m]
Al_2O_3	0.81	0.55	.....	0.13	.....		.....	.....	.....
SiO_2	.....	29.17	.....	.....	.....	Trace	2.12	20.58	.....
Na_2O	.....	.....	.....	2.86	.....	.....	.....	.....	0.16
K_2O	.....	.....	.....	0.29	.....	.....	.....	.....	0.06
F	.....	.....	.....	2.85	.....	.....	.....	.....	[e]Trace
BeO	.....	.....	.....	0.34	.....	.....	.....	.....	0.62
	99.93	99.75	99.03	100.25	98.95	100.57	99.50	100.73	100.48

[a] A, amorphous; I, isometric; O, orthorhombic; T, tetragonal.

[b] Isotropic or birefringent. Most of the determinations of optical properties are by E. S. Larsen and were not made on type material.

[c] $(Ce, La, Nd)_2O_3$

[d] N_2, He

[e] At. wt. 162.

[f] Y earths
A. 22.67 per cent. at. wt. 110.3
B. 5.30 per cent., at. wt. 110.53
C. 4.50 per cent., at. wt. 114.9
D. 14.03 per cent., at. wt. 120.

[g] Ignition

[h] $(Ce, Di)_2O_3$

[i] CO_2

[j] Ta_2O_5 abt. 2 per cent.

[k] UO

[l] Y_2O_3 abt. 1 per cent.

[m] Li_2O ?

Comparative Analyses of the Complex Uranium Minerals.—Continued.

(Arranged in order of their uranium content.)

Name	Near Samarskite	Hielmite	Blomstrandine	Pyrochlore	Fergusonite	Near Samarskite	Vietinghofite	Wiikite	Delorenzite
Page, Dana's System	740	741	App. 2, p. 17	726	730	740	740	App. 3, p. 85	App. 2, p. 34
Analyst	Hillebrand	A. E. Nordenskiöld	C. W. Blomstrand	Rammelsberg	W. H. Seamon	W. P. Hillebrand	A. Damour	Holmquist	J. Sterba
Crys. Form	.....	O	O	I	T	(?)	A	O	O
Isot. or bif.	.....	uniaxial (?)	Isot.	Isot.	Isot.	.....	.....	Usually isot.	.....
Indices	.....	ω=2.30 Li ϵ=2.40 Li	2.14	1.96	2.19	.....	.....	.....	.....
Sp.G.	6.18	5.82	4.82 4.93	4.22	5.6	6.18	5.53	3.8–4.8	4.7
Ta_2O_5	27.03	62.42	1.15	.....	4.08	19.34	.....	.....	.....
Cb_2O_5	27.77		23.35	58.27	43.78	27.56	51.00	23.67	.....
TiO_2	[a]	.....	27.39	5.38	.....	.....	1.84	29.58	66.03
UO	4.02	4.87	5.35	5.53[c]	5.81	.....	8.85[c]	1.86	9.87[m]
UO_2	.....	.....	.....	.....	.....	6.20	.....	7.37	.....
Ce_2O_3	0.54	1.07	2.48	5.50	0.66	0.41	1.57	.....	.....
(Di, La)$_2O_3$	1.80	.....	.....	.....	3.49	1.44	.....	.....	.....
Y_2O_3	6.41	5.19	25.62	.....	37.21	5.64	6.57	4.06	14.63
Er_2O_3	10.71	.....	.....	.....	.....	9.82	.....	.....	.....
ThO_2	3.64	.....	4.28	4.96	.....	3.19	.....	.....	.....
ZrO_2	2.29[a]	.....	1.33	.....	.....	3.10[a]	0.96	.....	.....
CaO	0.27	4.26	1.80	10.93	0.65	1.61	.....	4.86	.....
MgO	.....	0.26	0.15	.....	.....	0.11	0.83	.....	.....
WO_3	2.25	6.56	.....	.....	0.76	5.51	.....	.....	.....
SnO_2	0.95		0.18	.....		0.82	.....	.....	4.33
FeO	0.32	8.06	1.43	5.53	1.81	0.39	23.00	.....	4.25[m]
Fe_2O_3	8.77	.....	.....	.....	.....	8.90	.....	7.51	.....
MnO	0.78	3.32	0.30	.....	.....	0.77[g]	2.67	1.28[h]	.....
PbO	0.72	.....	0.84	.....	.....	1.07	.....	.....	.....
H_2O–	1.58	3.26	2.56	.....	1.62	3.04	1.80[j]	11.06	.....
X	0.29[b]	0.10[c]	0.49[d]	5.28[f]	.....	.....	.....	10.55[i]	.....
Na_2O	.....	.....	0.90	5.31	.....	0.36[k]	.....	.....	.....
K_2O	0.17	.....	0.18	.....	.....	.....	.....	.....	.....
	100.31	99.37	99.78	101.16	99.87	100.18	99.09	101.80	99.11

[a] Includes some TiO_2
ZnO 0.05
(Li, Na)$_2O$ 0.24
CuO

[b] ZnO 0.09
SiO_2 ..... 0.40

[c] FeO and UO

[d] Ignition 1.53
F 3.75

[e] MnO and ZnO

[f] (K, Li, Na)$_2O$

[g] U_3O_8

[h] Ignition

[i] Mn_3O_4

[j] Precipitated by H_2S 1.06
Al_2O_3 ..... 0.74
SiO_2 ..... 8.75

[m] State of oxidation not determined.

Comparative Analyses of the Complex Uranium Minerals.—Continued.

(Arranged in the order of their uranium content.)

Name	Euxenite	Euxenite	Samarskite	Plumboniobite	Nohlite	Altered Samarskite	Hatchettolite	Annerödite	Ampangabéite
Page, Dana's System	[a]	744	739	App. 3, p. 61	740	740	727	741	App. 3 p. 3
Analyst		Rammelsberg	Koenig	Hauser and Finkh	Nordenskiöld	W. H. Seamon	O. D. Allen	C. W. Blomstrand	Pisan
Cryst. Form	O	O	O	A	Massive	O	I	O	O?
Isot. or bif.	Isot.	Isot.	Isot.				Isot.		Isot.
Indices	2.24	2.24	2.10 2.25				1.98		2.13
Sp.G.	4.99	5.103	5.96 6.20	4.801 4.813	5.04	4.33	4.77 4.9	5.7[f]	3.97 4.29
Ta_2O_5	13.89			1.18			29.83		8.90
Cb_2O_5	12.73	33.39	56.40[g]	46.15	50.43	47.09	34.24	48.13	34.80
TiO_2	27.70	20.03		1.20			1.61		4.90
UO_3	10.50[b]	12.12	13.48	13.72	14.43[g]			16.28[g]	19.40
UO_2						15.15	15.50		
Ce_2O_3	0.62[c]	3.50	3.85		0.25	1.40		2.56	0.60
$(Di, La)_2O_3$						4.00			
Y_2O_3	25.64	14.60	11.90	14.26	14.36	13.46		7.10	4.00
Er_2O_3		7.30							
ThO_2	1.34			0.06				2.37	2.50
ZrO_2				Trace	2.96			1.97	
CaO	0.09	1.36		3.05	4.67	1.53	8.87	3.35	1.50
MgO	0.12						0.15	0.15	
WO_3									
SnO_2				0.15		0.40	0.30	0.16	0.80
FeO	0.51	3.25	8.98	5.70	8.09	7.09	2.19	3.38	
Fe_2O_3	2.63		1.66						8.60
MnO	Trace				0.28[h]			0.20	
PbO	0.20			7.62			Trace	2.40	
H_2O-	3.00	2.40	0.30	6.38	4.62	9.55	4.49	8.19	12.40
X	0.74[d]			0.52[j]	0.11[i]			2.51[k]	
Al_2O_3			2.00	0.28				0.28	2.10
Na_2O		0.82					1.37	0.32	
K_2O							Trace	0.16	
	99.71	98.77	98.57	100.27	100.20	99.67	98.55	99.51	100.50

[a] Miller, Willet G., and Knight, Cyril W., Occurrence of euxenite in South Sherbrooke township, Ontario: *Am. Jour. Sci.*, vol. xliv, pp. 243–244, 1917. Name of analyst not given. Analysis made at Imperial Institute, London, England.

[b] U_3O_8

[c] $(Ce, La)_2O_3$ etc.

[d] SiO_2

[e] Sp.G., 5.77

[f] N_2, He 0.22
CO_2 ..... 0.19
MnO 0.11
CuO ..... Trace

[g] UO

[h] MnO, MgO

[i] CuO

[j] Anhydrous mineral

[k] SiO_2
Ignition

Comparative Analyses of the Compex Uranium Minerals.—Concluded.

(Arranged in the order of their uranium content.)

Name	Polycrase	Samiresite	Mackintoshite	Blomstrandite	Pilbarite[i]	Betafite	Brannerite	Pitchblende	Uraninite
Page, Dana's System	745	App. 3, p. 69	App. 1, p. 44	746	.....	.....	.....	891	891
Analyst	Mackintosh	Pisani	Hillebrand	Lindström	Simpson	Pisani	Wells	Hillebrand	Hillebrand
Crys. Form	O	I	T	Massive	A	I	.....	I	I
Isot. or bif.	Isot.	Isot.	Isot.	Isot.	Isot.	Isot.	Isot.	Opaque	Opaque
Indices	1.70	1.94	1.77	2.14	1.74	1.92	2.30	.....	.....
Sp.G.	4.97–5.04	5.24	5.438	4.17–4.25	4.68	4.475	5.42	8.07	9.59
Ta_2O_5	.....	3.70	.....	49.76	0.47	Trace	.....	.....	.....
Cb_2O_5	19.37	45.80	.....		.....	32.10	.....	.....	.....
TiO_2	28.51	6.70	.....	10.71	.....	17.30	39.0	.....	.....
UO_3	.....	21.20	22.40	23.68[f]	.....	.....	10.3	58.51	57.43
UO_2	19.47	.....	.....	.....	27.09	28.60	33.5	25.26	26.48
Ce_2O_3	.....	0.20	45.30[d]	.....	0.19	1.20	.....	0.22	0.25
$(Di, La)_2O_3$	.....		.....	.....	.....		.....	.....	0.13
Y_2O_3	21.23[a]	.....	1.86[e]	.....	0.49	.....	3.9[h]	.....	0.20
ThO_2	.....	.....	.....	.....	31.34	1.25	4.1	.....	9.79
ZrO_2	.....	.....	0.88?	.....	.....	.....	0.2	7.59	.....
CaO	0.68	.....	0.59	3.45	0.57	11.61	2.9	0.84	0.08
MgO	.....	.....	0.10	0.16	0.21	.....	.....	.....	.....
SnO_2	.....	0.10	.....	.....	.....	.....	.....	.....	.....
FeO	2.47	1.06	1.15	3.33	.....	.....	2.9	0.32	.....
Fe_2O_3	0.18	.....	.....	.....	0.20	1.38	Trace	.....	0.40
MnO	.....	.....	.....	0.04	Trace	0.25	.....	0.16	.....
PbO	0.46	7.35	3.74	.....	17.26	.....	0.2	0.70	3.26
H_2O-	4.46	12.45[g]	0.50	7.96	3.50	5.20	2.0	1.96	0.61
H_2O+	.....	.....	4.31	.....	4.16	.....	.....	.....	.....
He	.....	.....	.....	.....	Trace	.....	.....	0.15[m]	Undet.
X	0.12[b]	.....	0.67[j]	0.12[k]	1.08[j]	.....	0.6[l]	1.45[n]	0.70[b]
Al_2O_3	.....	0.74	.....	0.11	0.15	0.50	Trace	.....	.....
SiO_2	1.01	.....	13.90	.....	12.72	.....	0.6	2.79	0.16
Li_2O	.....	.....	0.68	.....	.....	.....	.....	.....	.....
Na_2O	.....	.....		.....	0.04	.....	.....	.....	.....
K_2O	.....	0.30	0.42	.....	0.09	.....	.....	.....	.....
	97.96	99.60	96.50	99.32	99.56	99.39	100.2	99.95	99.49

[a] At. wt. 114.1
[b] Insol.
[c] Ignition
[d] ThO_2, Ce_2O_3
[e] La_2O_3, Y_2O_3
[f] P_2O_5
[g] UO
[h] Precipitated by H_2S
[i] Simpson, Edward S., Pilbarite, a new mineral from the Pilbara Goldfield: *Jour. Nat. Hist. and Sci. Soc. of Western Australia*, vol. iii, p. 131, 1911.
Lacroix, A., "Minéralogie de la France et de ses Colonies," vol. v, pp. 93–94. 1913.
[j] Mol. wt. 350
[k]

BaO	0.3
SrO	0.1
CO_2	0.2
P_2O_5	Trace

[l] Det. as N
[m] ZnO

ZnO	0.44
P_2O_5	0.22
As_2O_5	0.43
$CuFeS_2$	0.12
FeS	0.24

The only other minerals having the same general qualitative composition are zirkelite and delorenzite, and to make comparison easier their analyses are repeated.

Analyses of Zirkelite, Delorenzite, and Brannerite.

	Zirkelite Isometric	Delorenzite Orthorhombic	Brannerite Undetermined
Specific gravity	4.741	4.7	5.42
TiO_2	14.95	66.03	39.0
UO_2	1.40	9.87[a]	10.3
UO_3	.....	.....	33.5
Ce_2O_3	2.52	.....	.....
Y_2O_3	0.21	14.63	3.9
ThO_2	7.31	.....	4.1
ZrO_2	52.89	.....	0.2
CaO	.....	.....	2.9
MgO	0.22	.....	.....
SnO_2	.....	4.33	.....
FeO	7.72	4.25[a]	2.9
PbO	.....	.....	0.2
$H_2O\pm$	1.02 (ign.)	.....	2.0
Na_2O	10.79	.....	.....
SiO_2	.....	.....	0.6
BaO	.....	.....	0.3
SrO	.....	.....	0.1
CO_2	.....	.....	0.2
Fe_2O_3	.....	.....	Traces
Al_2O_3	.....	.....	
P_2O_5	.....	.....	

[a] State of oxidation not determined.

The uranium in zirkelite is almost negligible and the quantity of zirconium present puts it in a class by itself. The analysis of delorenzite makes the mineral appear almost suspiciously simple in composition, only five metals being determined, but the relationship to brannerite is closer than that of zirkelite. However, the quantity of uranium oxide is less than one-sixth that of the titanium oxide, but in brannerite the weight of uranium oxides is greater than that of titanium oxide and is more than four times as great as that in delorenzite.

The new mineral seems worthy of an individual name, and we therefore propose to call it brannerite after Dr. J. C. Branner, formerly head of the Department of Geology and Mining and President of Stanford University.

Brannerite may be described as a complex titanate of uranium with smaller quantities of rare earth and other metals, in which the weight of uranium oxides exceeds that of titanium oxide.

Industrial Employment of Very High Pressures. GEORGES CLAUDE. (*Comptes Rendus,* October 13, 1919.)—At present 200 atmospheres is about the maximum pressure used, and this chiefly in the Haber process and in the liquefaction of air. The author maintains that pressures of 1000 atmospheres can be more easily employed than those of lower amounts. Leather collars work all the better at higher pressures. It is not difficult to provide walls sufficiently strong to withstand high pressures, but it is difficult to secure tight joints. Owing to the smaller volume of containers at high pressure for the same mass of gas it is easier to make the joints tight for high pressures. As the cost of compression rises in proportion to the logarithm of the pressure the expense of compressing to 1000 atmospheres is one and a half times as much as of attaining 100 atmospheres.

G. F. S.

Some Characteristics of the Spark Discharge and Its Effect in Igniting Explosive Mixtures. C. C. PATERSON and NORMAN CAMPBELL. (*Proceedings Physical Society of London,* vol. xxxi, Pt. iv, 1919.)—For the ignition of mixtures of petrol and air a quantity of energy as small as .0004 joule was found to suffice. When the spark potential is lowered the quantity of energy requisite increases with great rapidity. A train of similar sparks has no greater igniting power than a single spark.

In the ignition of hydrogen and air it was found that reduction of the radius of curvature of the electrodes augmented the igniting power.

Experiments on an aeroplane engine showed that satisfactory ignition could be obtained by the use of quantities of energy much smaller than those supplied by a magneto or by a battery and coil system.

G. F. S.

The Speed of Sound Pulses in Pipes. A. L. FOLEY. (*Physical Review,* August, 1919.)—A sound pulse of cylindrical form was produced by an electric spark. It spread out from the line source, in part travelling in the open air and in part passing through various tubes set with their axes perpendicular to the line of the spark. This pulse was illuminated for an instant by a second spark and its shadow, due to its having a density different from that of the surrounding air, was caught and recorded on a photographic plate. The distance each portion of the pulse had come could thus be observed. It was found that the speed is greater or less in short tubes than in the free air, according to position with respect to the source, but that in longer tubes the speed, at first greater than in free air, gradually lessens and finally becomes smaller. The intensity of the pulse when it enters the pipe seems to be that which determines the speed. The greater the intensity the greater the speed.

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DISTRIBUTION OF ENERGY IN THE SPECTRUM OF AN ACETYLENE FLAME.[1]

By W. W. Coblentz.

[ABSTRACT.]

THIS paper gives new data on the distribution of energy in the infra-red spectrum of a flat and of a cylindrical acetylene flame.

This paper gives also a revision of previously published spectral energy data, pertaining to the violet end of the visible spectrum. This revision has no effect upon the previously published visibility, in the region of the spectrum in which the attempt has been made to attain high accuracy in the visibility data.

MAGNETIC TESTING OF STRAIGHT RODS IN INTENSE FIELDS.[2]

By W. L. Cheney.

[ABSTRACT.]

FORMER experiments, as performed by Ewing and Low, Pierce, Hadfield and Hopkinson, du Bois and Jones, Gumlich, Campbell and Dye, *et altera.*, to determine the intensity of magnetization with high magnetizing forces, involved the use of very small specimens. Frequently, it is desirable to make such tests with fairly long rods and since the usual types of permeaters do not permit the use of very high magnetizing forces, a method whereby magnetic tests can be made upon these rods in intense fields has been developed.

The apparatus consists essentially of a du Bois electro-magnet with flat pole pieces separated by an air gap and pierced coaxially so that a rod may be extended through them and the electro-magnet. Surrounding the specimen are three coaxial test coils wound on brass forms. When the inner coil is connected in series with

* Communicated by the Director.

[1] Scientific Paper No. 362.

[2] Scientific Paper No. 361.

a balistic galvanometer, the normal induction is measured by the throw of the galvanometer upon reversal of the magnetizing current. By connecting either the inner and middle or middle and outer coils in opposition the value of the magnetizing force is determined.

Normal induction curves obtained for a number of specimens of different materials show very good agreement with similar curves obtained by the Burrows method within the range of the latter. Hysteresis values, however, have not proved so reliable and are being studied further with the hope of satisfactory improvement.

From the normal induction data, the intensity of magnetization and reluctivity are calculated and discussed from the point of view of revealing in some specimens the presence of two constituents of different degrees of hardness which reach the maximum intensity of the magnetization for different values of H.

NOTE ON METHODS OF COMPUTING AND INTERCOMPARING RADIATION DATA.[3]

By W. W. Coblentz.

[ABSTRACT.]

A SIMPLE method is given for computing spectral energy curves using the Planck formula. A table of values of log $(e^u - 1)$ is given for this purpose. By means of this table, a table of logarithms and a slide rule, a complete spectral energy curve can be computed in an hour.

The paper gives also a chart for the intercomparison of thermal radiation constants with similar data, obtained indirectly from ionization potential, photo-electric and X-ray measurements.

CONCERNING THE ANNEALING AND CHARACTERISTICS OF GLASS.[4]

By A. Q. Tool and J. Valesak.

[ABSTRACT.]

THE characteristics involved in annealing were investigated for a number of glasses of different composition. The glasses

[3] Scientific Paper No. 360.
[4] Scientific Paper No. 358.

studied were chiefly those produced by the Bureau of Standards at Pittsburgh. Any common process of annealing may be considered as made up of three factors, namely: the annealing temperature, the time allowed for the reduction of the stresses, and the rate and mode of cooling.

One method which appears very dependable for determining the practical range of annealing temperatures consists of locating the temperature interval in which the glass on being heated shows a distinct and fairly sharp increase in the heat absorption. All glasses investigated showed this effect. It always occurred in a temperature range in which the glass was soft enough to allow a practically complete relaxation of the stresses in an unannealed sample in a very short period. The rapidly increasing softness of the glass at these temperatures and the increase in the heat absorption are undoubtedly related, but the nature of the relationship is as yet undetermined.

The rate of the relaxation of the stresses in the glass was determined at different temperatures by the use of two methods; first, by measuring the rate of deformation of loaded strips on rods; and, second, by determining the rate at which the double refraction in unannealed glass disappeared. The data thus obtained, as previous investigations also show, aid greatly in determining the practical annealing temperature, the time the glass should be held at this temperature, and a satisfactory cooling procedure.

THE CONSTANTS OF RADIATION OF A UNIFORMLY HEATED ENCLOSURE.[8]

By W. W. Coblentz.

[ABSTRACT.]

EXPERIMENTAL data are given on atmospheric absorption. The paper gives also a recalculation of the coefficient of total radiation of a uniformly heated enclosure, or so-called black body, giving a value of

$$\sigma = 5.72 \times 10^{-12} \text{ watt cm}^{-2} \text{ deg}^{-4}$$

The effect of atmospheric absorption is discussed, and the

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[8] Scientific Paper No. 357.

conclusion arrived at is that, if corrections are made for atmospheric absorption, the value recently obtained at Naples is close to the average value, viz.,

$$\sigma = 5.7$$

In the second part of the paper, the present status of the constant of spectral radiation is discussed.

THE ULTRA-VIOLET AND VISIBLE TRANSMISSION OF VARIOUS COLORED GLASSES.*

By K. S. Gibson, E. P. T. Tyndall, and H. J. McNicholas.

[ABSTRACT.]

DURING the last three years the spectral transmissions of a great number and variety of glasses have been measured by the Bureau of Standards throughout the ultra-violet, visible, and infra-red. The transmissions throughout the infra-red, and extending into the visible, have already been published,* as well as the transmissions for the visible and ultra-violet of glasses particularly classed as eye-protective.† In the present paper are given the transmissions for the visible and ultra-violet of 87 samples of glass, representing over 50 different kinds, mostly colored, which are not used primarily for eye-protection, but which are useful for various other special purposes. The glasses listed in this and the other papers mentioned, are representative of what may be obtained to-day on the American market, and include also some of foreign make which were obtainable before the war. It is thus possible to compare the relative merits of foreign and American glass, and see in what respect the latter may duplicate or improve upon the former.

All of the glasses of this paper, so far as it was possible to get values, were measured photographically and visually, and in most cases photoelectrically. The photographic (Hilger sector photometer with quartz spectograph) method may be used from

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* Technologic Paper No. 148.

* Coblentz and Emerson: B. S. Tech. Paper No. 93, May, 1917; 3rd edition, February, 1919. Coblentz, Emerson, and Long: B. S. Sci. Paper No. 325, August, 1918.

† Gibson and McNicholas: B. S. Tech. Paper No. 119, June, 1919.

230 to 500 millimicrons, the photoelectric (null method) from 380 to 600, and the visual (Koenig-Martens spectrophotometer) from 436 to 720. The data are presented in the form of transmission curves extending from 720 millicrons throughout the visible and ultra-violet as far as the specimens have any appreciable transmission. The methods overlap to such an extent that when all are used extremely reliable curves may be obtained. With possibly a few exceptions, therefore, the curves as given in this paper are considered accurate within 0.02 on the transmission scale of 0.00 to 1.00, and in many cases, especially at low transmissions and in the better specimens, the uncertainty is less than this.

For each specimen are given the transmission curve, the thickness, the trade name or designation, and the maker or dealer. In each figure also is given the relative visibility curve for the average human eye. An inspection of the curves must be made by those interested, inasmuch as this kind of data cannot be summarized.

Various practical uses to which these glasses are put are indicated, such as ultra-violet signaling, railway signaling, improvement of visibility both for visual and photographic work, protection of the eyes, and selective ray filters. Of special value in scientific work is their use as filters to obtain monochromatic light from the mercury, helium, or hydrogen lamps. Transmission curves of such filters are given.

NOTES ON THE MICROSTRUCTURE OF IRON AND MILD STEEL AT HIGH TEMPERATURE.[1]

By Henry S. Rawdon and Howard Scott.

[ABSTRACT.]

THE microstructure of iron and mild steel which prevails at high temperatures was studied by means of "heat-etching." The polished specimens were heated in vacuo to the desired temperature; volatilization of the metal from the surface is sufficient, together with the volume changes in the critical transformation, to produce an etched pattern on the previously polished face which

[1] Scientific Paper No. 356.

records the type of structure existing at that temperature. No change occurs in the type of microstructure upon heating until the temperature of the A_3 transformation is reached. Above this temperature the structure is radically different from that which prevails below.

The composition of the metal at the surface of the heated specimen changes considerably during the heating. The extent and nature of the change was determined; it is essentially a decarburization. Such decarburization does not occur until all the carbon is in the form of a solid solution, *i.e.*, until the temperature of the A_1 transformation is passed. The effect of this composition change upon the indications of the etching pattern by which the structure is revealed is discussed. This method of heat-etching is sensitive enough to reveal the true structure of the metal in spite of the change which occurs later in the composition of the surface metal.

THE EFFLUX OF GASES THROUGH SMALL ORIFICES.[1]

By Edgar Buckingham and Junius David Edwards.

[ABSTRACT.]

THIS paper contains a theoretical discussion of the results of experiments made during an investigation of the effusion method of determining gas density; and it is a sequel to the paper in which that investigation has already been described by one of the present authors.[2] The effect on effusion of viscosity and thermal conductivity of the gas are studied, and formulas for representing these effects are developed and compared with the observed facts. A physical interpretation is thus obtained for the most striking of the apparent anomalies observed in the behavior of gases flowing through very small orifices such as are used in apparatus for determining density by effusion. The mathematical work was, unavoidably, too cumbersome for satisfactory abstraction. The resulting agreement of the theory with the observations is exhibited graphically. It is fairly satisfactory but not perfect, and its imperfections suggest the directions in which further experiments should be made.

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[1] Scientific Paper No. 359.

[2] Edwards: Techn. Paper Bur. Standards, No. 94, June 20, 1917.

RECOMMENDED SPECIFICATION FOR BASIC SULPHATE WHITE LEAD.[8]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 22, 1919. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of this specification to a number of representatives of the paint and varnish industry, including all of the large manufacturers of white lead, and gave careful consideration to the replies received in time.

This specification gives chemical and physical requirements for dry basic sulphate white lead and basic sulphate white lead ground to a paste in linseed oil. Methods of sampling and methods of testing both dry pigment and the paste are made part of the specification. For details, the original should be consulted.

Benzol Poisoning.—According to R. P. ALBAUGH (*Modern Medicine*, 1919, i, 670), benzol or benzene is one of the most important industrial poisons. Poisoning due to benzene may occur in the manufacture of aromatic hydrocarbons, or in the technical use of products containing these hydrocarbons, *e.g.*, in the removal of grease from goods, and in the manufacture of varnish and rubber. The poisoning may be mild or severe, acute or chronic, and may have fatal results. When man is exposed to a mixture of benzene and air, he absorbs 80 per cent. of the benzene; the limit for animals is from 0.015 to 0.016 parts of benzene to 1000 parts of air. Distillations should be carried out in impervious apparatus with well-cooled condensers. All apparatus which has contained benzene should never be entered for cleaning or repairs until all benzene has been removed, and thorough ventilation has occurred. The workmen should have approved breathing apparatus. A person overcome by benzene should be removed into fresh air promptly, and given artificial respiration. Women are more susceptible than men to benzene poisoning.

J. S. H.

[8] Circular No. 85.

Platinum in 1919. (*U. S. Geological Survey Press Bulletin*, No. 435, December, 1919.)—The platinum market during the first quarter of 1919 was easier than in 1918, owing to the facts that the governmental restriction on the use of platinum had been removed and that the Government was disposing of its surplus stocks. The low price of $99 an ounce was reached late in March and was maintained about a month, but the price gradually stiffened until August, when the Government stocks were exhausted, and then abruptly rose to $110 an ounce. Since the middle of August the price has continued to advance about $5 an ounce a month, the demand for the metal has been strong, and the supply has been short.

During the first nine months of 1919 about 40,400 ounces of platinum were imported, and importation at this rate will probably be continued during the rest of the year, so that if the normal domestic production of 7000 to 10,000 ounces is maintained, about 54,800 ounces of new platinum should be available, aside from the stocks of platinum, about 65,000 ounces, held at the beginning of 1919.

So far as known there has been little change in the domestic mining of platinum. The wide search made in 1918 for domestic sources of platinum has apparently yielded little results. Colombia may supply more crude platinum in 1920 than in the past, but its producing capacity is limited by the methods employed in washing the gravels from which the metal is obtained. Practically no supplies can be expected from Russia for several years. The osmiridium field of Tasmania appears to need only higher prices to stimulate larger production, but even with this stimulus it can probably produce not much more than 2000 ounces a year.

According to James M. Hill, of the United States Geological Survey, Department of the Interior, there seems to be little hope of any marked increase in the output of platinum in the United States or Canada over the small output heretofore made, and as the supplies are below normal and the demand is large it is reasonably certain that the price of platinum metals in this country during 1920 will be at least as high as it was during the last quarter of 1919, and possibly higher.

Energy Requirements of Man.—*The Weekly News Letter, U. S. Department of Agriculture*, December 31, 1919 (vol. vii, No. 22, page 3-4), states that a family consisting of father, mother, and three children requires approximately 12,000 calories per day. These may be divided into 120 portions of 100 calories each. The diet is best balanced by dividing these 120 portions among certain groups of foodstuffs: Fruits and vegetables, 24; milk, eggs, and meats, 36; cereals and legumes, 30; sugar and sugary foods, 12; fats and fatty foods, 18.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

INTENSIFICATION AND REDUCTION WITH PYRO DEVELOPERS.[1]

By R. B. Wilsey.

It is well known that a pyro developed negative has a greater printing density and contrast than a neutral negative of equal visual density and contrast. The strength of the pyro color can be varied over a wide range by suitably altering the concentrations of the constitutents of the developer, especially that of the sulphite. These facts suggested the possibility of using the pyro color as a means of photographic intensification, or its removal to produce photographic reduction. A pyro negative may be bleached in a ferricyanide bleach without losing its color, and redeveloped in a pyro developer to produce another deposit of stain and thus intensification, or it may be bleached in a permanganate bleach, removing the color, and redeveloped in a formula giving it a lower photographic contrast. A neutral negative may be bleached in either ferricyanide or permanganate bleach, and intensified by redeveloping in a pyro developer.

These various possibilities were investigated with sensitometer strips made upon Seed 30 plates. Printing contrasts were determined from prints upon positive motion picture film. It was found that a negative of normal pyro color (developed in pyro 5–10–10) could be reduced to about half its original photographic contrast by bleaching in permanganate bleach and redeveloping in elon-hydroquinone. By bleaching in ferricyanide bleach, and redeveloping in pyro without sulphite (pyro 5–10–0), the printing contrast was nearly doubled. The printing contrast of an elon-hydroquinone negative was doubled by bleaching in permanganate bleach and redeveloping in pyro 5–10–0. Lesser degree of reduc-

* Communicated by the Director.

[1] Communication No. 83 from the Research Laboratory of the Eastman Kodak Company, published in *Phot. J. Amer.*, 1919, p. 558, and *Brit. J. Phot.*, 1919, p. 721.

tion or intensification was obtained by redeveloping in pyro developer having a suitable concentration of sulphide.

The process of intensification was repeated five times upon a single negative, which gave it a printing contrast nearly three times that of the original negative. The advantages of this method are that, within certain limits, any degree of intensification or reduction can be produced by suitable variations in the sulphite concentration of the redeveloper; the reduction or intensification is proportional, the contrast being changed by the same ratio for all parts of the negative. The degree of reduction or intensification that can be obtained compares favorably with that of other methods.

Desiccated Vegetables.—PHILIP B. HAWK of Jefferson Medical College (*Science*, 1919, xlix, 329–330) comments on the behavior of desiccated vegetables. When they are immersed in water for a few hours they assume a form closely approaching that of the fresh vegetable. If the swollen mass be removed from the water and permitted to remain at room temperature for twenty-four to thirty-six hours, it returns to the anhydrous state, and therefore behaves in an entirely different manner from a fresh article. Hence a fresh vegetable and a swollen desiccated vegetable are entirely different structurally. The failure of the swollen desiccated product to retain its water as well as the fresh article may be due to a change in the colloids of the vegetable cells with an accompanying decrease in their power to hold water, or may be due to removal of salts during the soaking and a resulting decrease in inhibition power of the colloids.

J. S. H.

Utilization of the Rhone in French Territory.—In August, 1919, the Senate and the Chamber of Deputies adopted articles providing for this great engineering work. The estimated cost is 2,500,000,000 francs and fifteen years will be spent on the project. From Lake Geneva to the Mediterranean there is a fall of 372 metres. It is estimated that 1,800,000 horsepower can be developed. "The Rhone represents a mine as rich as all the coal fields of the north of France," a fortunate circumstance for France in view of the systematic destruction of her coal mines by the Germans.

In addition to the development of power the navigation of the river will be improved. At present there is almost no use made of the stream from Geneva to Lyons as a waterway. Water for irrigation will be provided for the departments of Gard, Bouches-du-Rhone and elsewhere.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

VANILLYL ACYL AMIDES.[1]

By E. K. Nelson.

[ABSTRACT.]

THE author's investigation of capsaicin,[2] which demonstrated that substance to be a vanillyl decenoyl amide, has led to the synthesis of a number of other vanillyl acyl amides (4-hydroxy-3-methoxy benzyl acyl amides), of the type $(4)HO(3)CH_3O.C_6H_3(1)CH_2NHCOR$.

The condensation products of vanillyl amine with acetic, propionic, butyric, isobutyric, *n*-hexoic, *n*-heptoic, *n*-octoic, *n*-nonoic, *n*-decoic, *n*-undecoic, *n*-dodecoic, crotonic, undecenoic and benzoic acids have been prepared and described. Optical-crystallographic data are given. The products from valeric, isovaleric, cinnamic and two decenoic acids failed to crystallize.

In the homologous series of derivatives of saturated fatty acids, the solubility in water decreases, while the solubility in ether increases, with rising molecular weight. Pungency to the taste, absent in vanillyl acetamide, increases to a maximum in vanillyl *n*-nonoylamide, which is about as pungent as capsaicin, one eight-thousandth milligram of either substance causing a distinct burning on the tip of the tongue. Pungency in the derivatives of still higher molecular weight decreases or changes in character, becoming less quickly evident and affecting the back of the tongue and throat.

These relations run parallel with the observations of Backman [3] and Durrans [4] on odorous substances, which showed, respectively, that a substance, to be odorous, must be somewhat soluble in both water and lipoids, and that, in homologous series, the maximum odor is found in substances of intermediate molecular weight.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, vol. xli, Dec., 1919, pp. 2121–30.

[2] Nelson: *J. Am. Chem. Soc.*, vol. xli, 1919, p. 1115.

[3] Backman: *J. physiol. path. gen.*, vol. xvii, 1917, p. 1.

[4] Durrans: *Perfumery and Essential Oil Record*, vol. x, 1919, p. 104.

LABORATORY EXPERIMENTS ON THE MANUFACTURE OF CHINESE ANG-KHAK IN THE UNITED STATES.[8]

By M. B. Church.

[ABSTRACT.]

ANG-KHAK or red rice, a common Chinese vegetable color, is used in food products of China. Its character is due to the growth of certain strains of a mold, *Monascus purpureus* Went, throughout specially treated rice kernals. This mold is so utilized only in the Orient. Certain strains of the same fungus have been found in America in corn silage and on "freckled" salt codfish. The finished red rice is composed of clear-cut grains of a dark red color, and crumbles easily into a fine, soft, red power. On contact with watery solutions, it breaks down into similar fine particles. In the manufacture of red rice the water content of the uninoculated rice must be suitably adjusted. Temperature also must be considered. In these laboratory experiments a 25 per cent. water content at room temperature (22-24° C.) was successful. Other water contents caused the mold-infected rice grains to split into flinty fragments rather than to break down into a powder. As the physiological activity of each strain of *Monascus purpureus* may vary quantitatively, it is necessary to resort to the selection of strains in order to produce successful red rice.

Flax Growing Within the Empire. (*Journal of Royal Society of Arts,* November 7, 1919.)—Before the war Britain needed about 100,000 tons of this fibre. Seventy to 80 per cent. came from Russia, while Belgium, France and Holland contributed a total of 10 per cent., and Ireland as much. The over-running of the flax-growing parts of France and Belgium was followed by the collapse of Russia. This was met by an extension of the acreage under flax in Scotland and England, but especially in Ireland, where in 1914 there were 49,000 acres and in 1918 143,000, chiefly in Ulster.

The present outlook for an adequate supply of flax is not satisfactory. It is not yet determined whether it is possible to establish the industry permanently in Great Britain under modern conditions of wages and machinery. G. F. S.

Revue Générale de l'Electricité, November 15, 1919, contains an illustrated article by GEORGE P. ROUX on "The Energy Distributing System of the Philadelphia Electric Company." Special emphasis is laid upon the "load dispatcher" and the apparatus employed by him. G. F. S.

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[8] Published in *J. Ind. Eng. Chem.*, vol. xii, No. 1, Jan., 1920, p. 45.

NOTES FROM THE U. S. BUREAU OF MINES.*

EXPERIMENT STATION OF THE BUREAU OF MINES.

By Van H. Manning.

In the ten years that have elapsed since the Bureau of Mines was first established its centres of activity have increased in number from a single station, at Pittsburgh, to eleven stations at strategic points, the most remote being at Fairbanks, Alaska. Each station has its part in the work of the Bureau as a whole and it also has an integral function as the local centre for Federal aid to the mineral industry. In Bulletin 75 of the Bureau of Mines the equipment and the work that has been and is being done at each station is described in sufficient detail so that anyone familiar with the work of only one station can secure an adequate idea of what is being done elsewhere, and what the facilities of the Bureau as a whole are. The safety and rescue stations of the Bureau are also briefly described in this Bulletin for although these are not properly experiment stations, some investigative work on mine sanitation and hygiene is carried on at them.

USE OF BREATHING APPARATUS IN GASOLINE VAPORS.

By A. C. Fieldner, L. H. Katz, and S. P. Kinney.

The use of oxygen-breathing apparatus in gasoline vapors of high concentration is attended with considerable danger because the vapor permeates the rubberized fabric of the breathing bag. Jas. S. Cunningham, foreman miner of the Bureau, lost his life through entering a gasoline storage tank while wearing such apparatus. Tests have therefore been made of the effect of gasoline vapors on breathing apparatus, and these experiments show that the thin rubberized coating used on the Salvus half hour oxygen-breathing apparatus is rather easily penetrated by both liquid gasoline and high concentrations of gasoline vapor, such as may be expected in a tank containing some volatile casinghead gasoline. While ordinary motor gasoline does not seem

* Communicated by the Director.

to produce high enough concentrations of gas to penetrate in dangerous quantities through a bag free from defects in a period of 10 to 15 minutes, yet the need of a much more impermeable bag is certainly demonstrated.

The bags now furnished with some half hour types of breathing apparatus, such as the ones tested, consist of cloth fabric coated with a thin rubber cement-like material that is decomposed by gasoline and is penetrated by the vapors in a much greater degree than the heavier rubber fabrics used on the two hour types of apparatus. These heavier bags must also be under suspicion for such purposes until thoroughly investigated.

The Bureau of Mines is taking up this subject with a view to recommending more impermeable materials not attacked by gasoline or similar liquids. In the meantime, users of oxygen-breathing apparatus in high concentrations of gasoline, benzol and other organic vapors should observe all precautions and always attach a life line to the wearer so that he can be immediately drawn out of the dangerous atmosphere should he show distress.

WASTE AND CORRECT USE OF NATURAL GAS IN THE HOME.

By S. S. Wyer.

NATURAL gas is a community asset and every consumer has a right to demand that wasteful use be prohibited in the interest of the general service. Of all the gas sold as a public utility service in the United States, three-fourths is natural gas. The average price of natural gas to the domestic consumer is 30 cents per thousand cubic feet; the average price of manufactured gas is $1.00 per thousand cubic feet. Of the natural gas delivered to the domestic consumer 80 per cent. is wasted through the use of inefficient appliances for its burning. By relatively simple and inexpensive adjustments in such appliances it is quite possible to make one cubic foot of gas do the work now done by 3 cubic feet. This would make a gas supply available for consumers who are now unable to obtain any, and postpone the time when, through exhaustion of the natural supply, consumers will generally have to turn to the use of manufactured gas. Details as to the sources of waste in the use of natural gas in the home, and the means which should be adopted for their cor-

rection are given in a Technical Paper of the Bureau of Mines. A conference called by the Secretary of the Interior met in Washington January 15, as a result of which a committee of 10 was appointed to take suitable steps to lessen this loss.

MINOR NOTES.

Smoke Nuisance.—Salt Lake City has a serious problem in the smoke that is being generated within the city limits and the City is coöperating with the Bureau of Mines in studying the problem and ascertaining the steps to be taken for its solution. Determinations of the soot fall during October indicate that it ranged from 8.6 to 37.9 tons per square mile. As the hypothesis had been advanced that the smoke from the smelters drifted in above the city and prevented the city smoke from rising and becoming dissipated, one of the Bureau investigators made an airplane flight above the city to take samples of the air at the upper levels. These showed only a trace of SO_2, indicating that smelter smoke was not present in appreciable amounts.

Colorado Oil Shales.—A coöperative agreement has been entered into between the Bureau and the State of Colorado for the expenditure of $10,000 under the direction of the Bureau on investigations of the oil shales of Colorado. The work is to be done at the University of Colorado, where laboratory facilities have been provided. M. J. Gavin, of the Bureau, has been designated to have charge of the work.

Geophone Tests.—Recent tests made with the geophone indicate that nickel diaphragms give a greater range for intercepting sound waves than any material previously tried. In a recent test at Mullan, Idaho, the geophone successfully located a leak in a 12-inch buried water main after a great deal of money had been spent in attempting to locate the leak by ordinary means, but without result.

Coal Inspection.—The estimates for appropriations for the Bureau for 1920–1 contain an item providing for the creation of an inspection and certification service for coal much like the present inspection of meats, except that it will not be compulsory, reliance being placed on the advantages of the service to secure its general adoption. The mining companies would set their own standards for their average product. Sampling plants would be

established at strategic points and enough of the coal passing these points would be sampled to determine whether the standard of product is being maintained or not. That adequate sampling methods can be easily provided is obvious to anyone familiar with smelter sampling in the western United States. This would give the consumer a means of knowing what he is buying, and, while it is not part of the plan, it seems probable that coal of guaranteed quality would sell at a sufficient premium to cover the cost of sampling.

Tunnel Atmosphere.—The New York and New Jersey Vehicular Tunnel Commission has asked the Bureau to undertake an investigation of the atmospheric conditions likely to exist in the tunnel under conditions of normal use, especially from the standpoint of the effect of the exhaust gases from motor vehicles. A series of road tests on 80 motor vehicles, both passenger cars and trucks, is well advanced and chamber tests on human subjects in a chamber representing a section of the tunnel are about to be started. The road tests give results differing somewhat from the block tests, heretofore available, as might have been expected. Vehicular tunnels are being constructed in other cities and the results will be of general service, as well as furnishing further data on the use of internal combustion engines underground.

Atomic Orientation. T. R. MERTON. (*Phil. Mag.*, October, 1919, p. 463.)—The atoms in a crystal are arranged in a regular manner. Each atom has one or more electrons revolving about a nucleus at the centre. A line through this nucleus and perpendicular to the orbital plane is the axis of the atom. Are these atomic axes oriented in a regular manner within the crystal or are they pointed in all directions? A second question is this: If the crystal is radioactive does the direction in which the alpha and beta particles are thrown off bear some fixed relation to the atomic axis?

To seek an answer to the two questions proposed the alpha ray activity was investigated from different faces of crystals of uranium nitrate. No difference was found. Thus either or both questions appear to have a negative answer.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 21, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 21, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 5.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-Presidents, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Coleman Sellers, Jr., Vice-President (to serve three years).

Charles Day, Vice-President (to serve one year).

Cyrus Borgner, Treasurer (to serve one year).

Gellert Alleman, G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, George D. Rosengarten, William C. Wetherill, Managers (to serve three years).

Howard Graham, C. C. Tutwiler, Managers (to serve one year).

A vote of thanks was extended to the tellers for their services.

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1920, with the reports of the various standing committees of the Institute and Board of Managers.

The President then announced that the Aero Club of Pennsylvania was meeting jointly with the Institute, and requested Mr. Joseph A. Steinmetz, President, to preside.

Mr. Steinmetz introduced Dr. J. C. Hunsaker, Commander, Construction Corps, U. S. Navy, Navy Department, Washington, D. C., who presented the communication of the evening, entitled "U. S. Naval Aircraft." Consideration was given to the development of aircraft for the Naval Air Service as influenced by Naval requirements. An account was also given of the engineering investigations upon which the design of modern Aircraft is based. Detailed descriptions were given of the various seaplanes, balloons and airships which were used during the recent war by the Navy. Guns and gunmounts, torpedo carriers, bomb-carrying devices and other auxiliary apparatus were fully described. The subject was illustrated by numerous lantern slides.

On motion, duly seconded, a rising vote of thanks was extended to Commander Hunsaker for his interesting paper.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 7, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 7, 1920.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2740: Barker Wrenchless Chuck. Howard N. Potts Medal awarded to Wendell Addison Barker, of Elkhart, Indiana.

The following report was presented for first reading:

No. 2733: Hays Automatic CO_2 and Draft Recorder.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section, the Aero Club of Pennsylvania, and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 8, 1920, at 8 o'clock.

Dr. George A. Hoadley opened the meeting on behalf of the Institute, and introduced as the presiding officer Dr. Thomas D. Cope, President of the Physics Club, who presented the speaker of the evening, Dr. David L. Webster, Captain, Aviation Section (flying status), Signal Officers' Reserve Corps; Assistant Professor of Physics in the Massachusetts Institute of Technology. Dr. Webster delivered an illustrated lecture on "The Physics of Flight," in which the fundamental physics of flight and their application by the pilot were described.

The communication was discussed by Drs. Russell, Ives, Cope, and Webster, and Lieutenant Wetherill. On the motion of Dr. Russell, a vote of thanks was extended to Dr. Webster. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section, the Philadelphia Section of the American Institute of Electrical Engineers, and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 15, 1920, at 8 o'clock. Dr. George A. Hoadley on behalf of The Franklin Institute, Dr. C. E. Clewell on behalf of the American Institute of Electrical Engineers, and Dr. Thomas C. Cope on behalf of the Physics Club, presided jointly. The minutes of the joint meeting of January 8th were read and approved.

Dr. Clewell introduced Lee de Forest, Ph.D., Sc.D., of New York City, who delivered an illustrated lecture on "The Audion—Its Action and Some Recent Applications." The history of the Audion was traced from the original gas flame detector, through the two-electrode vacuum detector and valve, to the three-electrode relay or modern Audion. An account was given of the application of the Audion as a telephone repeater, generator of alternating

currents of both high and low frequency, autodyne and heterodyne receiver, and transmitter for radio telephone and telegraph, and of its use in the directional receiving and in "wired and wireless," and for other purposes.

After a discussion of the communication, a rising vote of thanks was extended to Dr. de Forest, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, January 14, 1920.*)

RESIDENT.

MR. FREDERIC E. BALDWIN, retired, 2200 Walnut Street, Philadelphia, Pa.

PROF. MONROE B. SNYDER, Director of Philadelphia Observatory, Central High School, Broad and Green Streets, Philadelphia, Pa.

NON-RESIDENT.

MR. WILLIAM C. BRINTON, JR., Chief Engineeer, Philips-Brinton Company, Kennett Square, Pa.

MR. EDWIN S. PHILIPS, President, Philips-Brinton Company, Kennett Square, Pa.

MR. EDWARD E. WHITE, Civil Engineer, Glen White, West Virginia.

CHANGES OF ADDRESS.

MR. WALTER ATLEE, 1709 John Street, Baltimore, Md.

MR. JOHN VAUGHAN BOSTWICK, 257 S. 16th Street, Philadelphia, Pa.

MR. CHARLES E. FOSTER, St. George Road, Ardmore, Pa.

MR. GEORGE BERKELEY REED, U. S. Submarine School, New London, Conn.

MR. THOMAS SPENCER, 3523 Balsam Avenue, Indianapolis, Ind.

MR. G. A. WELLS, 352 William Street, East Orange, N. J.

MR. ALAN WOOD, 3rd, Georgetown, S. C.

LIBRARY NOTES.

PURCHASES.

BARNETT, E. DEB.—Coal Tar Dyes and Intermediates. 1919.

CAIN, J. C.—Manufacture of Intermediate Products for Dyes. 1919.

DINGER, H. C.—Hand-Book for the Care and Operation of Naval Machinery. 1918.

JONES, H. C.—Hydrates in Aqueous Solution. 1907.

KAPP, GISBERT.—Principles of Electric Engineering, vol. ii. 1919.

MEAD, D. W.—Hydrology, the Fundamental Basis of Hydraulic Engineering. 1919.

MORLEY, ARTHUR.—The Strength of Materials. 1919.

National Association of Railroad Commissioners, Proceedings No. 30, 1918.

NUTTING, P. G.—Outlines of Applied Optics. 1912.

PRENTICE, C. F.—Ophthalmic Lenses. 1907.

Readers' Guide to Periodical Literature, Supplement No. 7. 1919.
SCHENCK, RUDOLPH.—Physical Chemistry of the Metals. 1919.
STANLEY, RUPERT.—Text-Book of Wireless Telegraphy. 2 vols. 1919.
TEED, P. L.—Chemistry and Manufacture of Hydrogen. 1919.
West Virginia—Geological Survey, County Reports and Maps. Fayette Co. 2 vols. 1919.
WHITTAKER, C. M.—Application of the Coal Tar Dyestuffs. 1919.

GIFTS.

Alberger Pump and Condenser Company, Catalogue F. New York, 1919. (From the Company.)
Alexander Brothers, Engineering Data. Philadelphia, Pa., 1919. (From Alexander Brothers.)
Allied Machinery Company of America, Catalogue of Metal Working Machinery. New York, no date. (From the Company.)
American Institute of Mining and Metallurgical Engineers, Transactions, vol. lx. New York, N. Y., 1919. (From the Institute.)
Austin, F. C., Company, Inc., Catalogue No. 7. Chicago, Ill., 1919. (From the Company.)
Bailey Meter Company, Bulletins Nos. 30 and 41. Cleveland, Ohio, 1919. (From the Company.)
Bicycle Manufacturers' Association, Catalogue of Industrial Transportation. Hartford, Conn., 1919. (From the Association.)
Bound Brook Oil-less Bearing Company, Booklet of Oil-less Bushings. Bound Brook, N. J., 1918. (From the Company.)
Canada Department of Mines, Bulletin No. 30. Ottawa, 1919. (From the Department.)
Celite Products Company, Bulletin describing standard engineering practice in insulating various types of furnaces. New York, 1919. (From the Company.)
Chapman Valve Manufacturing Company, Catalogue No. 38. Indian Orchard, Mass., 1919. (From the Company.)
Clarage Fan Company, Catalogues Nos. 6, 11 and 51. Kalamazoo, Mich., no date. (From the Company.)
Clark Equipment Company, Booklet, Putting Mettle into Metal. Buchanan, Mich., 1919. (From the Company.)
Cooper, Hugh L., and Company, Catalogue, Hydro-Electric Developments. New York, no date. (From the Company.)
Dunton, M. W., Company, Booklet, Soldering Kinks. Providence, R. I., 1919. (From the Company.)
Edwards, O. M., Company, Inc., Catalogue W-19. Syracuse, N. Y., no date. (From the Company.)
Foxboro Company, Inc., Bulletin No. 104-1. Foxboro, Mass., 1919. (From the Company.)
Galbraith, C. C., and Son, Inc., Booklet of Steamship and Shipyard Supplies. New York, no date. (From the Company.)
Gem City Boiler Company, Catalogues 419 and 519. Dayton, Ohio, no date. (From the Company.)

Gifford-Wood Company, Catalogue No. 35. Hudson, N. Y., 1919. (From the Company.)

Goulds Manufacturing Company, Bulletin No. 122. Seneca Falls, New York, 1919. (From the Company.)

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BOOK NOTICES.

AIR SERVICE MEDICAL MANUAL. War Department. Air Service. Division of Military Aeronautics. 38 pages text, illustrations, plates, 8vo. Washington Government Printing Office, 1918.

Flying, which has now become one of the important features of warfare, and has found some applications in the arts of peace, involves much danger, from defects of machinery, atmospheric conditions and psychology of the

pilot. It is to the last-mentioned condition that this book is devoted. In each of the countries that were at war recently there is an established medical service. The British have organized their service as practically an independent arm, under a Surgeon General of Aeronautics. The United States service is handled by a division of the office of the Surgeon General of the Army. The book is divided into two parts, Part 1 being a brief statement of general facts, including some account of Langley's pioneer work in the construction and operation of the heavier-than-air machine. Part 2 is a detailed presentation of the facts in regard to the psychical requirements of those who undertake to act as pilots, and gives information as to the methods of testing. The numerous illustrations, many of them from photographs, others sketches, aid greatly in understanding the subject. Among the photographs are several showing planes after fatal accidents. In connection with a picture of the wreck of a plane after falling 500 feet, it is stated that only 8 per cent. of such accidents are due to defects in machines. Ninety per cent. are due to defects in pilots. It is also stated that pilots that are physically disqualified for very high flights can serve with satisfaction on bombing machines, which are usually flown at comparatively low levels.

A claim is made that Germany was the first country to recognize the value of the airplane in war, inasmuch as it is stated that when the Wrights took their biplanes to Europe, the French, English and Italians regarded the possibilities of flight only from a "sporting" point of view, but the Germans took up at once the warlike application of the machine. Apart from the fact that balloons had been used for such purposes at least as early as the War of Secession, it is not true that the ingenuity of the German had outdistanced the United States for the Wrights did not take their planes to Europe until 1903, and President McKinley, in 1898, taking note of the success with the model "aerodrome," in 1896, suggested to Langley that he should take up the construction of a man-carrying plane, because he (McKinley) saw the "great possibilities of a flying machine as an engine of war." ("Langey Memoir on Mechanical Flight," p. 124.)

HENRY LEFFMANN.

COURS DE CHIME A L'USAGE DES ÉTUDIANTS P. C. N. ET S. P. C. N. By R. Forcrand, University of Montpellier. 2nd edition, two volumes, 8vo, totalling 954 pages of text. Tables of Contents, but no index. Paris, Gauthier-Villars et Cie. List price, 32 francs; temporary rate, 64 francs.

The shortcomings of this work to which the reviewer deems it proper to call attention may be due in part to the stress and storm under which it was written, but probably largely to the purpose, as avowed, that it is intended for students competing for special certificates. This latter condition will always limit a writer's field.

So far as the work in general is concerned, it may be said that it contains a good deal of information within its almost one thousand closely printed pages. About seventy pages of the inorganic portion are taken up with generalities, most of which material is somewhat similar to the introductory matter of the manuals of chemistry half a century ago, termed often "Chemical Physics." Of physical chemistry, in the sense in which the term is understood to-day, there is but little. A brief notice is given of the phase rule, but

the important subject of hydrogen-ion concentration is not mentioned. In the section of the cyclic compounds, the theories of benzene and of the interesting stereochemistry of these substances are not presented. The author seems indeed to have a strong feeling against reference to German scientific works, for Kekulé and Fischer are not mentioned in connection with the lines of work that they have so brilliantly illuminated. In the section of sugars, levulose is termed l-fructose instead of d-fructose. The relations of colloid chemistry and catalytic action, now so important and interesting, are touched but little. In the classification of the elements, the author uses the division into metalloids and metals, though he shows by several statements that this classification is unsatisfactory. A considerable part of the second volume is taken up with methods of analysis and stoichiometry. Carbon and its oxides are described in connection with organic chemistry, a plan which seems to the reviewer to be of doubtful value.

The lack of an index is very exasperating.

HENRY LEFFMANN.

MESURES PRATIQUES EN RADIOACTIVITÉ. Par W. Makower et H. Geiger, Traduit de l'Anglais, par E. Philippi. 175 pages, index and contents. 8vo. Paris, Gauthier-Villars et Cie. Price 16 francs.

This is a translation of the authors' book entitled "Practical Measurements in Radioactivity" issued in 1912. The original is not at hand, so comparisons cannot be made to determine the accuracy of the translation, but inasmuch as both authors probably understand French, and communications between Paris and London are now rapid and convenient, it is not likely that any important error has occurred; moreover, the translation of simple categoric statements such as make up the greater portion of a work of this type is not difficult. The advisability of translating a book seven years old (the preface to the English edition is dated 1912) without bringing the matter up to date is questionable. No attempt has been made by the translator to cover the literature that has appeared since the publication of the original, at least there is no reference later than 1912, and no translator's preface or even any note or suggestion by him. An appendix giving references to dealers that can furnish materials or apparatus for studies in radioactivity contains six names, of which three are German firms. So far as the matter of the book is concerned, it is presented in a concise clear form, illustrated with numerous simple but satisfactory drawings, and printed on good paper and with clear type.

HENRY LEFFMANN.

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Walrus Hide as a Metal Polisher. (*Brass World,* November, 1919, vol. xv, No. 11, p. 326.)—The Arctic is populated with herds of walrus, somewhat similar in appearance to the seal but larger.

The walrus runs from 12 to 15 feet in length and weighs between 1500 pounds and a ton. His tusks measure 10 or 20 inches long. To-day, in addition to certain other uses, it is found that walrus leather, on account of its tough fibre and extra thickness, is superior to any other medium for polishing metals.

Closely and firmly grained, the tough flexible fibre of this leather will hold in its meshes such materials as pumice, emery, crocus and other abrasive or polishing substances. When its own abrasive qualities are added we have a medium which will produce on any metal a clean and smooth surface, durable and brilliant.

The hide of the walrus runs anywhere from ½ to 1½ inches in thickness. In fact, so variant will a single skin be that the trade has built up the custom of quoting thickness by measuring a specified point at the middle of the back. But a wheel cut from any part of a good skin, regardless of what the local thickness be, gives a solid polishing surface of commensurate width and insures an even friction on any surface to which it is applied. The skin can also be cut in strips and mounted on wooden wheels.

R.

CURRENT TOPICS.

The Wood Alcohol Peril.—Methyl alcohol is found abundantly in commerce in two forms, the crude "wood spirit," which contains acetone and tar products, and the highly rectified form, which contains no appreciable impurities, except a small proportion of water. The crude form has a characteristic disagreeable odor, and does not seem likely to be used as a beverage even by inadvertence, much less by intention. The pure form has but little odor and mixed with water and colored may be drunk without warning. This form has long been sold for manufacturing purposes under misleading names, such as "Columbian spirit" and "Colonial spirit," the latter term being especially objectional on account of liability to be confused with "Cologne spirit," the most highly rectified form of grain alcohol commonly found in commerce. As even the purified methyl alcohol was much cheaper than tax-paid ethyl alcohol under the pre-war rates and was not subject to Government control, the temptation to use it in many preparations, such as varnishes and medicines, was very great, and shortly after it began to be a commercial article cases of poisoning began to occur. The earlier cases were mostly of slow poisoning, that is, due to the drinking or inhalation of small amounts at frequent intervals, and the most prominent symptom was blindness due to organic changes in the nervous supply of the eye. Taken in larger doses it acts as powerful poison, often with fatal results.

Attention has lately been directed to the subject, owing to the many cases of acute poisoning caused by the substitution of methyl alcohol for ordinary alcohol, on the part of those who have the drink habit. So far the data have been principally set forth in newspaper accounts and the exact analytic results have not been available, but Dr. Reid Hunt, now at the head of the Division of Pharmacology at Harvard University, prepared for the *Amer. Chem. Soc. News Service* (Bulletin 251) some important and interesting facts. He states that "wood alcohol" has become known as the "American poison" on account of the numerous cases that have been reported in this country. It was shown in a trial some years ago that manufacturers of flavoring extracts had been approached by dealers in wood alcohol and urged to make their preparations with it. The fact that already at that time the bottles bore the label "poison" was explained as a ruse to prevent the Government from placing an internal revenue tax upon wood alcohol.

It is interesting to note that when methyl alcohol was first

brought into general notice (many years ago), Dr. Benjamin Ward Richardson, a prominent English physiologist, basing his opinion on analogies then generally accepted, stated that the substance probably would come into general use as a substitute for ordinary alcohol on account of its more transient effect.

Individuals differ considerably in their susceptibility to wood alcohol; some die or become blind from amounts which seem to do no harm to others. This is true, however, of all poisons. Death or blindness has resulted from two teaspoonfuls and one or two tablespoonfuls of the poison. Sixty to seventy-five of those taking four ounces, that is, a quarter of a pint or half a glassful, have died or become permanently blind. That wood alcohol is properly placed in the list of deadly poisons is evident from the fact that the mortality from arsenic poisoning is only fifty to seventy-five per cent. and that from mercury dichloride even less. Of a group of 130 men who drank a mixture of wood and grain alcohol all but 32 died or became blind.

Crude methyl alcohol is one of the ingredients of denatured grain alcohol, and as this article is sold at less than a dollar per gallon against about eight times that sum for beverage alcohol under present tax laws, the temptation to use the impure liquid is very great. It is claimed by some that many of the recent cases of methyl alcohol poisoning have been of this type, but until scientific reports are available, positive opinion on this point must be reserved. A striking fact is that in many of the States in which prohibition has been established for years, scarcely any cases of wood alcohol poisoning have been reported.

In a case of poisoning recently reported (*Jour. Amer. Med. Assn.*, January 3, 1920, p. 25) a portion of the liquid remaining in the bottle was found to contain 87 per cent. methyl alcohol.

H. L.

The Fuel Problem.—The dominance of oil as a fuel grows apace. A very interesting review of the question is presented by Professor Chester L. Jones, of the faculty of the University of Wisconsin, but at present Commercial Attaché to the American Embassy at Madrid. The article entitled "Caribbean Petroleum" appeared in *Oil News* (December 20, 1919), and calls attention to the efforts steadily pursued by the British to secure control of oil fields, and points out that the United States should make efforts in the same direction, and especially to prevent foreign control of the oil sources in the West Indies. Oil-burning steamships are rapidly replacing those using coal, and if improvements in the Diesel engine continue, even steam-driven ships may find competition too severe. A Scotch ship with Diesel engines has just been turned out, which, it is estimated, can run from London to Australia and half way back on one loading of oil. A report on the *Lusitania* some months before it was sunk stated that if

oil could be used as fuel, ninety per cent. of the firemen could be dropped, and it is further stated that the *Mauretania* could be navigated with 27 firemen in the place of over 300 now employed. A ton of oil takes five cubic feet of space less than a ton of coal, and produces more steam. Oil is not subject to shifting in rough weather, and the machinery does not need any more repairing than with coal. As oil increases the ship's steaming radius, the maintenance of fuel stations is less exacting.

In 1907 Great Britain and Russia made a treaty dividing Persia into "sphers of influence," Russia taking a northern portion and Great Britain a southern, leaving a small middle area for the Persians. The southern area, which it seems has lately been confirmed by a new treaty, contains the oil sources, and this is, of course, the secret of the British action. Notwithstanding Great Britain's immense possessions, these include few oil lands, and hence the present activity of that nation.

Professor Jones states that all around the Caribbean area are indications of undeveloped oil sources, and three are now producing the material. Trinidad delivered over one million and a half barrels in 1917, and a larger yield is reported for 1918. In Venezuela an oil region is developing around Lake Maricaibo. A British company has a concession in Venezuela covering over six million acres.

In this connection some statements that have appeared in the *Mexican Review* (vol. iii, 1919, No. 7, p. 10) are interesting. They relate to the business of the Royal Dutch Shell, as it is now known in the stock market. The "Shell Transport Company" was formed about twenty years ago with a capital of nearly $10,000,000. Its issued capital is now over $50,000,000 and the market value of the shares is about $350,000,000. About twelve years ago the interests of this company were fused with the Royal Dutch Petroleum Company and the assets of both companies were transferred to a British company (The Anglo-Saxon Petroleum Company) and a Dutch company. Of the shares 60 per cent. are held by the Royal Dutch and 40 per cent. by the Shell. The properties of the concern are in Dutch Indies, Rumania, Russia, Egypt, Mexico, Sanawak and the United States.

Sir Marcus Samuel is Chairman of the Shell Company. For sometime past the company has paid dividends of 35 per cent. Its affairs have lately been much discussed in financial circles, because of an expected acquisition of a big interest in the Mexican Eagle Oil Company which has an issued capital of $25,000,000 and declared last year year a dividend of 25 per cent.

H. L.

A New Commercial Sugar. (*Information Circular*, U. S. Dept. of Agriculture.)—The sugar question has become one of the most important phases in the high cost of living. Not only is the price

high, but the supply seems to be far below the requirements of the people. The United States has for many years had the largest consumption among all countries, the ratio being usually over 80 pounds per capita. Starch-sugar has been manufactured in large amount as a substitute for sucrose, but has not been entirely satisfactory for some of the important table uses. The U. S. Department of Agriculture has been for some time investigating proposed substitute sugars and has found the promising one to be maltose, that is, the sugar of malt. Malt is sprouted grain, in which the starch has been more or less converted into a sugar having the same chemical composition as cane sugar, but not identical with it. It has long been known but only recently has it been considered for specific manufacture on the large scale. Two factors have contributed to this result. The establishment of national prohibition will allow a considerable volume of grain that would otherwise be fermented to be utilized, and the plants necessary for the manufacture of the sugar will be already in part at hand in the breweries that will be no longer used for making malt liquors. All the important cereals can be used in the process. The principal installation that breweries will need will be vacuum evaporating pans, which are well-known forms of apparatus. Malt syrup has much resemblance to maple syrup, its use on the table may not be as convenient as common sugar, but it is an excellent substitute, as it has the same caloric value. For cooking and baking purposes, and for some forms of candy, it is in some respects superior to the common form. It is now being used largely in baking and soft-drink plants. It is now quoted in recent papers about 9 cents per pound in large lots. As yet, owing to the absence of any appreciable demand from housewives, grocers are not carrying the article, but it is likely that as its merits become widely known it will be as familiar as corn syrup.

Although the present propaganda is principally due to the cane sugar shortage, yet the new sugar is likely to find wide use in many ways, even in the household, as it is an excellent, wholesome syrup of delicious flavor. H. L.

Académie Royale de Belgique. (*Bulletin de la Classe des Sciences,* 1919, No. 1.)—This, the first number published after the retreat of the Huns from Belgium, fairly throbs with historic interest. At the meeting of January 4, 1919, in Brussels, the Director for 1914, M. P. Pelseneer, said in his address: "Since the last time we were assembled events of unparalleled gravity have come to pass. In contempt of treaties a nation claiming to be civilized attacked without motive a little people, both peaceful and inoffensive, of whose neutrality it was a guarantor. Entire regions have been sacked, civil populations have been massacred, cities have been destroyed or set on fire with their treasures of art or ancient libraries,

thousands of families are in mourning." He pays tribute later to "our powerful Allies who fought at our side for the same ideal."

In the correspondence is a communication from the University of Ghent to foreign universities directing their attention to the work of destruction carried on in that city by the agents of Prussian militarism aided by official representatives of learned Germany.

A "Brief Report on the Condition of the Palace of the Academies after the Departure of the Germans" throws vivid light on the Kultur of the invaders. A caretaker entered this building in Brussels a few days after the Armistice and was met by an overpoweringly vile smell. Two decomposing human bodies were found in the basement. The secretary describes his first visit to the former seat of the Academy of Sciences on November 18, 1918. "With some of my employés I made a rapid visit with nose and mouth covered by protecting material. A dreadful stench reigned everywhere. Neither pen nor pencil can give an idea of the abominable scene our rooms presented. From the very door of the vestibule of the left wing we had to hunt for places to put our feet in order to avoid stepping in excrement. Everywhere was the same filth, the same disorder, the same destruction—broken panes in the windows, the bronze and copper parts of doors carried off. The libraries were topsy-turvy; there were many gaps on the shelves."

An official pig-pen was found in the garden. It is not known what kind of shame hindered the Germans from lodging its inmates in the interior of the Palace, an act which would hardly have changed the appearance of the latter. The products, however, of the piggery were found as hams and pieces of bacon in the chamber of the Royal Historical Commission, which was transformed into a butcher shop.

A series of a dozen reproductions of photographs displays in lasting form to the scientists of the present and of the future the condition of the various rooms of the Palace. The "Salle américaine" containing the publications of the learned societies of the United States was completely emptied. The books which were dumped in the attic are gone.

In its last pages the bulletin reverts to its pre-war scientific aspect where is found a discussion of certain algebraic curves by M. M. Stuyvaert.

G. F. S.

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